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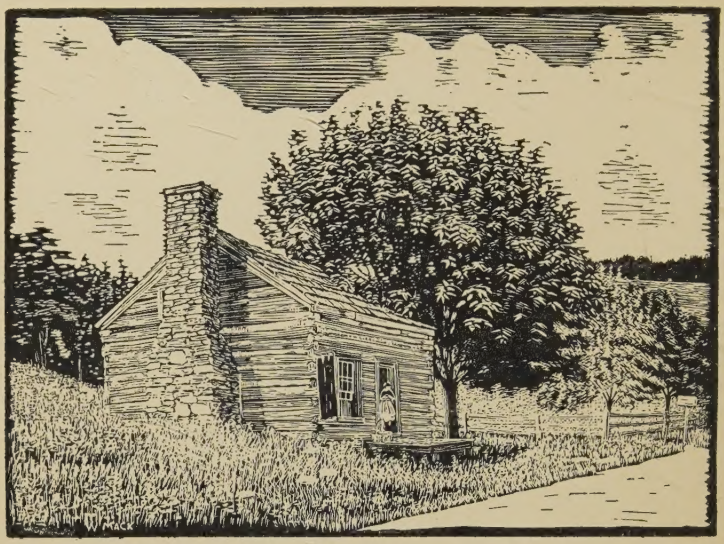

A small cottage, poore for stuffe and rude for workmanship.

—Ascham, 1568

THE SIZE AND COMFORT OF OUR DWELLING HOUSES, THE BEAUTY OF OUR CLOTHING, THE VARIETY OF OUR FOODS, AND THE NATURE OF OUR AMUSEMENTS ARE DETERMINED BY HOW POOR OR RICH WE ARE IN STUFF

STUFF

The Story of Materials in the Service of Man

By PAULINE G. BEERY

S.F. PUBLIC LIBRARY

NEW YORK AND LONDON

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1930

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PRINTED IN THE UNITED STATES OF AMERICA

THIS BOOK IS INTENDED
FOR EVERY PERSON INTERESTED IN
THE ROMANTIC STORY OF THE STUFF
USED IN DAILY LIFE, BE HE
EIGHT OR EIGHTY

PREFACE

Strife for stuff! That is what much of life is.

Whether one stops to think of it or not, the chief difference between the hungry and the well-fed, the homeless and the well-housed, the poor and the rich—is simply stuff.

Perhaps it will bring the importance of stuff to mind to consider what you would do if you were cast, like Robinson Crusoe, upon an uninhabited island in mid-ocean. To make matters worse, pretend that you do not have Crusoe's good fortune in recovering an important assortment of articles from the ship's wreckage, or in having a good man Friday turn up to act as valet and general assistant in searching the island for whatever stuff it has to offer.

You are now in the situation of prehistoric man. For your food and clothing you must find whatever the place affords, and make the best of it. You must find shelter in some naturally sheltered spot. Then, having provided yourself with the barest necessities of life, you will turn your efforts to the search for other stuff which will increase your comforts and give pleasant relief from monotony.

You will be better off than prehistoric man in many respects, and worse in others. You can devise things more readily than he, because you know something about them. You will only be replacing things which you know, instead of inventing new things. But you will certainly be more discontented than he, without the comforts and pastimes which you have come to consider as a matter of course. You will soon find out that you can make no progress without stuff from which to make the things you need. How will you get iron for your implements? Where will you provide the simplest substances with which to season your food, as, for example, sugar and salt?

In your struggle for stuff, you will be repeating in a short space of time much of the history of mankind. Man's progress from age to age has depended upon the number of materials which he knew how to secure and use. Commerce between nations is the result of a desire to obtain new kinds or greater quantities of stuff from other

lands. Wars have been fought to gain possession of regions where certain important stuffs can be secured. Much of man's history is thus the story of his search for the stuff which will be of service to him.

P. G. B.

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STUFF

CHAPTER I

A ROYAL FAMILY OF ANCIENT TIMES

Egypt from whose all-dateless tombs arose
Forgotten pharaohs from their long repose.
—Byron

THE only knowledge we have of prehistoric man's search for the stuff needed for his everyday existence is that which we arrive at by conjecture. Historical records, either those which man deliberately wrote, or those which he left incidentally in the nature of buried articles of necessity or luxury, extend back little more than five or six thousand years. On the borderline between the prehistoric and the historic ages in Egypt—one of the earliest of civilized countries—a Pharaoh named Snefru lived and reigned. The date of his reign has been variously placed by historians from 2500 to 4000 B.C. He built himself a pyramid of no mean size, although it could not compare with the later great pyramids which still stand and are a never ending source of wonder to all who behold them.

Snefru's pyramid, long since fallen into ruins, has been excavated in modern times, and the articles placed there before his death for the use of his spirit in the after-life have been recovered. From a study of these articles, together with the scattered inscriptions that he left, we are able to draw a few conclusions concerning the progress which had been made in his day in man's struggle for stuff.

In a tomb connected with Snefru's pyramid, the statues of a prince and princess named Rahotep and Nefert were found. All evidence seems to point to the fact that these royal per-

sonages were Snefru's son and daughter. We can tell something of what the prince and princess looked like from the statues pictured there. They were carved in limestone and painted to look as much like human beings as possible. The eyes of the statues were made of ivory, quartz, and dark ore. Altogether these are the most lifelike of any of the ancient Egyptian sculptures.

Rahotep, according to his statue, did not burden himself with excessive clothing. He did not even adorn himself with an extravagant display of jewelry, according to the custom of later Egyptian royalty. Although native gold had been found in his time, it had not been produced in large enough quantities to make its use common even for the ornaments of princes. If Rahotep set the styles for the young men of his period, as was doubtless the case, he made no great demands either upon cloth merchants or jewelers.

Nefert, on the other hand, is shown to be clad in a simple white dress. The garment represented in the statue was probably of linen, as befitting the rank of a princess. We are led to believe this because linen and wool were the only textile fabrics known in Egypt at that time, and because linen was thought to be the only cloth fit for royalty. Wool, being considered unclean, was used only by the common people.

Nefert's chief ornament, shown in the statue, was a rather elaborate necklace. It is probable that the jewel pendants hanging from this necklace consisted of turquoises. At least we know that the princess could have had all the precious stones of this kind that her heart desired, since King Snefru came into possession of extensive turquoise mines during his reign.

EMERGING FROM THE STONE AGE

All evidence points to the fact that Snefru and his family lived in the latter part of the Neolithic or Smooth Stone Age in Egypt. This was the age in which people had come to

PRINCE RAHOTEP AND PRINCESS NEFERT COULD WELL BE SMUG!

They never found out how much they missed.

make more highly refined articles of stone than had been fashioned during the Paleolithic or Rough Stone Age, which stretched back thousands of years into the remote past. Utensils of polished stone, pieces of clay pottery, and highly

refined articles of flint were found in the ruins of his tomb. More significant still was the presence of many ornaments of turquoise and malachite and of a few small articles of copper, chiefly needles.

Turquoise and malachite are compounds of copper, which may be smelted to produce the free metal if heated to a sufficiently high temperature with wood or charcoal. The fact that copper needles and other tiny copper articles were found among the cherished articles owned by King Snefru indicates that the people of his time were beginning to practice the art of smelting copper in small quantities.

PREHISTORIC DISCOVERY OF SMELTING

Whether the art of smelting was practiced in Egypt for the first time during Snefru's reign, or whether it was handed down to Snefru's generation by a previous age, is not known. Conjecture has it that many centuries were consumed in developing the art, even to the point where sufficient metal for making a needle could be produced.

It is interesting to picture the probable accidental discovery of the first piece of metal. Domestic fires of early times were built in the open, inside a ring of stones, much like a picnic fire of to-day. The stones used for this purpose were chosen at random from those which happened to be at hand. There is little doubt that stones containing copper ore were frequently picked up by prehistoric man, since such rocks are not uncommon. A rock of this sort might easily have fallen out of place and become embedded in the embers while some family of remote times was preparing a meal. Or, a stone deliberately heated as a resting place for a cooking utensil may have been the first ore to be accidentally smelted in such a way as to cause it to give up the metal combined in it. In either case, the process of smelting took place in a manner not differing in principle from methods in use to-day.

The small irregular mass of reddish metal that was first prepared in this accidental way undoubtedly excited the wonder of somebody when it was found among the ashes. It probably lay around as a curiosity for some time, however, before it was discovered that it could be hammered into various shapes.

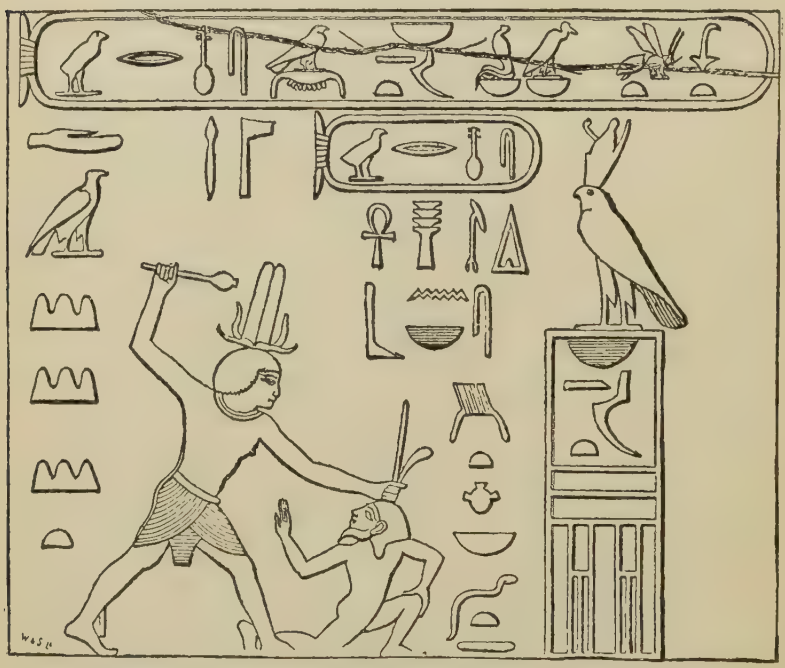
SNEFRU, THE FIRST LARGE-SCALE MINE OPERATOR

Although historical records fail to give us any information concerning the discovery of smelting, they are fairly complete as to the circumstances surrounding early developments in the mining industry. Strangely enough the first mining enterprise of any significance was undertaken for the purpose of procuring ornaments. The first mine of which we have records was a turquoise mine located on a triangular bit of mountain-covered land known as the Peninsula of Sinai, which shoots a wedge-shaped spur into the Red Sea.

The Sinai copper mines were developed at an early date by tribes inhabiting these regions, who had noticed that the sides of the mountains were rich with bright-colored substances embedded in the sandstone. They mined these blue turquoises, and other copper ores of bright and green colors, and sold them without realizing that they could be melted and copper obtained from them. Egypt was the chief market for these stones, and the turquoise industry was at its height during the reign of Snefru.

King Snefru was particularly glad to secure these materials, but he decided to dispense with the necessity of paying for them. Consequently he sent forth expeditions of his own men to sweep down upon this region called Mafkait or "land of turquoises" by the Egyptians. The natives naturally resented this intrusion, but they were overpowered by force of numbers. The Egyptians then set to work to operate the mines. They introduced many improved methods and increased the output considerably. Because the natives frequently sent down bands

to attempt a recovery of their lost possessions, Snefru built a fort and established watchmen to protect the workmen in their labors. Royal inspectors arrived from time to time to investigate conditions and to speed the output.



KING SNEFRU DEMONSTRATES HIS PROWESS AS A CONQUEROR

The tablet of Snefru, the ancient Pharaoh, carved on a rocky cliff at the turquoise mines of Sinai, shows him beating down an enemy.

The ruins of the fortress and of the deep well which Snefru made to supply his troops and workers with water can still be traced near the mines of Sinai. On a rocky cliff nearby, inscriptions were left by Snefru in order that generations that came after should know of his achievements as a conqueror and mine operator.[1]

[1] Snefru's tablet stood in its original place, defying the elements for more than five thousand years. In 1906, however, a party of English scientists visited the place and found a turquoise mining outfit at work and ruining

LUXURIES OF FIFTY CENTURIES AGO

In this modern day of ours, when we possess such a great number of materials from which to make the many objects that we use in our everyday activities, it is interesting to pause for a moment to consider the things possessed and used by a royal family living at the time when man was passing from the Stone Age to the Age of Metals. Of course they used air, our most important kind of stuff. Nature has seen to it that man does not have to search for this commodity. Water, too, man's next most important substance, is plentiful, ranking next to air in accessibility.

For food, the members of our royal family of some half a hundred centuries ago had a much less extensive outlay of products than we have to-day, although they did not fare so badly as one might think. They had meat of various kinds, including fowl and fish; bread made of whole wheat; a few fruits; and a few such vegetables as leeks, peas, onions, lentils, and garlic. They knew the art of preserving foods such as fish by salting them, as shown in the following illustration. They even carried this process so far as to preserve fish by drying them.

The Egyptians chose their rations very much more carefully than did other ancient peoples. They even regulated the diet of the king's household by law, so that the ruler and the heir to the throne might eat nothing that would endanger their health.

The Egyptians of the time of Snefru, Rahotep, and Nefert had wood fires in neat stone fireplaces, but no flues for carrying off gases, and the fireplaces were frequently out of doors. They had beds, but the beds had no springs—since steel was

---

the inscription with their blasting. This expedition consequently hastened to preserve Snefru's tablet and those of other Egyptian rulers who had been at work at the mines, and they removed these from the mountain sides and placed them in the museum at Cairo.

not known. They could have had feather pillows if they had wanted them, because fowls constituted one of their chief articles of diet.

If an Egyptian of that time became ill, he received as good

AN ANCIENT EGYPTIAN FISH MARKET

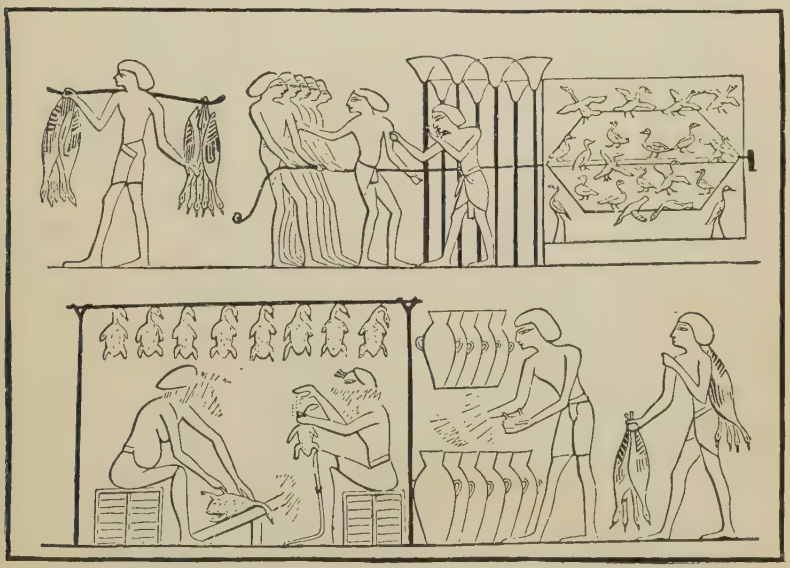
The catching, marketing, and even the drying and preserving of fish was a well established industry in the days of the Pharaohs. (Above, painting from the tomb of Beni Hassan: on page 9, painting from the great pyramid.)

attention as the limited number of materials available would allow. The physicians had only herbs as their source of drugs, however, and they could not practice surgery beyond crude bone-setting and the performance of other minor operations.

As for amusements, Rahotep and Nefert did not fare so well. Music was limited to singing and to the playing of a few tunes

on lyres with flaxen strings and on flutes made of bamboo. No doubt many games were devised, although none is described in the crudely carved historical records of the day.

King Snefru doubtless was more successful in finding ways of passing the time than were the prince and princess. The ancient Egyptian kings had so many activities to supervise



FRESH FOWLS, ALIVE OR READY DRESSED, IN ANCIENT EGYPT

Snefru and his family could enjoy duck dinners and feather beds, even though potatoes and steel bed springs were not yet known. (Copy of a painting from a tomb in ancient Thebes.)

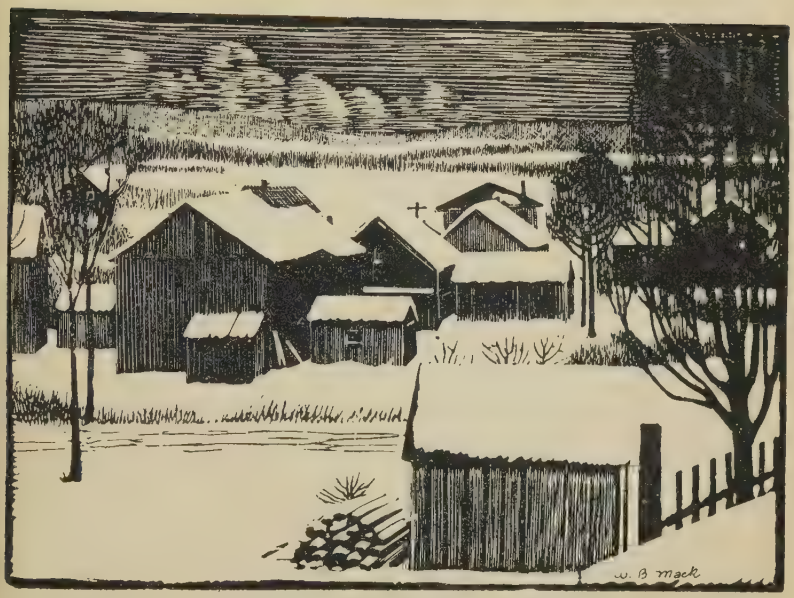
that they are said to have been the busiest of people in olden times. Snefru, therefore, probably did not miss the forms of entertainment that we have grown accustomed to to-day. He would, however, have found some of our modern time-saving devices quite useful in his many undertakings. The telephone and telegraph would no doubt have given him sufficient leisure to take up golf in the modern manner had it been played then.

WHAT THEY MISSED

Although King Snefru, Prince Rahotep, and Princess Nefert had all the kinds of stuff known by the human beings of fifty centuries ago, they certainly missed a great deal by not having delayed their appearance on earth until now. What would they have thought if they could have been projected into our modern life for a brief half day! Telephones, autos, radios, television, the X-ray, newspapers and books, the movies and talkies, Mazda lamps, railways and airplanes, gorgeously colored textile fabrics, and a multitude of other modern-day objects in common use undoubtedly would have baffled them completely.

No doubt it is better that Snefru, Rahotep, and Nefert never had an inkling of what they were missing. They probably compared the luxury of their own age with that of ages before, as it was repeated to them in legend and tradition. They no doubt wondered how people managed to exist in primitive bygone days—days before fire was known, when people wandered from place to place with no fixed dwelling, days when only the crudest of tools, utensils, and implements were fashioned from wood or rough stone. The expressions on the faces of their statues, which seem lifelike indeed, show smug satisfaction with everything in general.

Perhaps fifty centuries hence the people of the time will look back at us and wonder why we could be so well contented when we had so little.



BACK YARDS

Everybody has nitrogen and oxygen in his back yard, and in his front yard, too, for that matter. The air above one square mile of the earth's surface contains about twenty million tons of nitrogen and five and one-third million tons of oxygen, as well as lesser amounts of so-called rare gases.

CHAPTER II

A BREATH OF FRESH AIR

Loud wind, strong wind, sweeping o'er the mountains,
Fresh wind, free wind, blowing from the sea,
Pour forth thy vials like streams from air fountains.
Draughts of life to me.

—D. M. Mulock

AIR is the most important kind of stuff that the human being uses after he is ushered into this great and mysterious existence called life. He continues using it in small but regular amounts as long as he lives. Fortunately it is free, although some of its ingredients are prepared commercially for purposes other than breathing, and are bought and sold for a price.

Jack Cluett, writing some time ago for *Judge,* describes in facetious vein the human propensity for breathing:

Go and watch the baby when he is asleep. See how his chest rises and falls, then rises and falls again, just like the stock market, all by itself, with no attachments or force pumps.

He does not know what he is doing, he is not interested, he is too young to inhale.

He began to breathe on Tuesday night, and he will not stop for a heck of a while, unless you put corks in his nose. If you were to awaken him and say: "Pardon me, baby, but you are breathing," he would look surprised and say: "Goo." He does it without thinking.

There is a patent bellows in each of us that takes care of our breathing when we are asleep. If this machine becomes too noisy, somebody will sock you, and you'll have to start all over again, after the carbon has been removed. Don't think you're smart just because you can breathe—almost every one can do it.

See how long you can hold your breath without cheating. Isn't it capital fun?

In some places men dive in the ocean for pearls. They are called clam-diggers and can't breathe under water. They pick up the empty shells on the bottom and the longer they stay under, the more shells and exhausted they get. They don't dare to take a breath because the salt water makes them thirsty. Yet even these pearl divers cannot go without an occasional breath.

FEAR OF FRESH AIR

Important as air is, our ancestors feared it, and lived almost hermetically sealed lives. Many of the illnesses that they were subject to were the result of their fear of this substance. Benjamin Franklin, who was considerably ahead of his time, wrote the following in 1773:

The gentry of England are remarkably afraid of moisture and of air, but seamen, who live in perpetually moist air, are always healthy if they have good provisions. . . . I have long thought that mere moist air has no ill effect on the constitution. But we abound in absurdity and inconsistency. Thus, though it is gen-

erally agreed that taking the air is a good thing, yet what caution against air. What stopping of crevices! What wrapping up in warm clothes, what shutting of doors and windows, even in the midst of summer. Many London families go out once a day to take the air, three or four persons in a coach, one perhaps sick; these go out three or four miles, or as many turns in Hyde Park, with the glasses both up close, all breathing, over and over again, the same air they brought out of town with them in the coach, with the least change possible and rendered worse and worse every moment; and this they call "taking air"! From many years' observation on myself and others, I am persuaded we are on the wrong scent in supposing moist or cold air the cause of that disorder we call a "cold." Some unknown quality in the air may sometimes produce cold, as in the "influenza," but generally, I apprehend, they are the effects of too full living in proportion to our exercise.

SOMETHING ABOUT AIR

The word *air* comes from an Indo-European root meaning "to breathe"; but the composition of air was not known, and the reason for breathing was not established until long after the word was in common usage.

In the earliest ages of which we have records, the theory seems to have prevailed that there were four elements—earth, water, air, and fire. These were thought to have been created first, and the whole world to have been produced from them.

Galileo, an Italian scientist who lived from 1564 to 1642, established the material nature of air by discovering that a copper globe filled with compressed air increased in weight.

Some time later John Mayow, an English scientist living from 1645 to 1679, showed that air was chiefly a mixture of two gases—one of which supports life and burning, and the other of which is apparently inert. Mayow did not separate air into these two gases, nor did he give them names.

Daniel Rutherford, an English nobleman who delved into scientific matters, found in 1772 that animals kept in a closed

MINE VENTILATORS OF THE MIDDLE AGES

The importance of air was appreciated long before the reason for its necessity was understood. These three ingenious devices were used to operate bellows for changing the air in mine tunnels in the sixteenth century. (Woodcut from Agricola, *De Re Metallica*, Book VI, *circa* 1556.)

space for some time changed a part of ordinary air into a gas which clouded limewater.

We now call the two gases of air to which Mayow first called attention oxygen and nitrogen. The gas which Rutherford found to be generated by breathing animals has received the name carbon dioxide.

From the latter part of the eighteenth until well past the middle of the nineteenth century people believed that air was a mixture of two gases, oxygen and nitrogen, with very small amounts of carbon dioxide. They never thought of the possibility of its having any other constituents. Because the careful analyses of two English scientists, Rayleigh and Ramsay, showed a discrepancy of a little less than one per cent of what the total volume of air should be, it was found between the years 1868 and 1898 that air contains also comparatively small amounts of five rare gases—helium, neon, argon, krypton, and xenon.

The cave man of course knew nothing of the composition of air. Neither did King Snefru or his smug son and daughter, Rahotep and Nefert, nor any of the other people of the ancient civilized countries. No doubt they could breathe quite as successfully as we, at least under ordinary circumstances.

Then why, some Philistine will say, should we bother with such details?

Why, indeed?

WHAT IS A GAS?

We have been speaking quite freely of gases. How do gases differ from other types of materials? To be sure, we know that the air must be a gas. It certainly could not be a solid, nor a liquid either, for that matter, unless we all were changed into fish. Even fish, although they live under water, require that the water be saturated with oxygen, which they use in breathing. Wherein, therefore, do gases, liquids, and solids differ so materially from each other?

The above is a fundamental question which applies to all kinds of stuff. Even the popular writers, Nina Wilcox Putnam and Ring Lardner, in recent articles, have recognized the difference between that which scientists call "the states of matter." "Say It With Bricks," says Mrs. Putnam in an article in which she gives her opinion of husbands. "Say It With Oil," counters Lardner in his reply on the peculiarities of wives. That there is a difference between these two substances is so apparent to all of us that we scarcely give the matter a moment's thought.

When we come to think of it, however, we cannot help but wonder why a brick is so much more substantial than oil. Other questions also come to mind. Why does syrup pour more slowly than water? Why can you throw a ball through the air, although you cannot throw a bunch of air through a ball? Why will water pour through a sieve, while bricks will not? Why is it that, when you pull along one end of a stick, the other end comes following after?

All of these questions, and others equally as simple-sounding and yet important, can be answered by considering the fundamental structure of stuff.

STRUCTURE OF STUFF

As far back as man has been able to reason he has pondered over the structure of stuff. He has asked himself whether, if one could divide a drop of water into two parts, and then continue this process, he could go on dividing the subdivisions indefinitely; or whether he would finally arrive at an ultimate particle which could no longer be subdivided and still consist of water. The ancient Egyptian, Hindu, and Chinese philosophers, and later the Greek and Roman thinkers, speculated and debated upon this same point. Debating was as far as they could go, however, since they had no scientific laboratories in which they could place their theories on trial.

Even without laboratories, the ancient adherents to the theory of the discontinuity of matter worked out by means of logic an elaborate set of premises for their molecular theory. Somewhere along the line some one coined the word *molecule*, meaning tiny mass, to refer to *the smallest particle of any substance which can exist and still have all of the characteristics of that substance.*

To be sure, we of the present day, with our extraordinary laboratory facilities, know that materials are composed of unbelievably small units called, as the philosophers of old ordained, molecules. We know further that these molecules move at a very rapid rate and that there is a space between them which is greater even than that taken up by the molecules themselves. Further than this, we know that molecules have an internal structure elaborate beyond all belief. Atoms, protons, and electrons, however, can wait their turn for consideration, just as they did in the history of scientific thought. We are concerned now only with molecules as a whole.

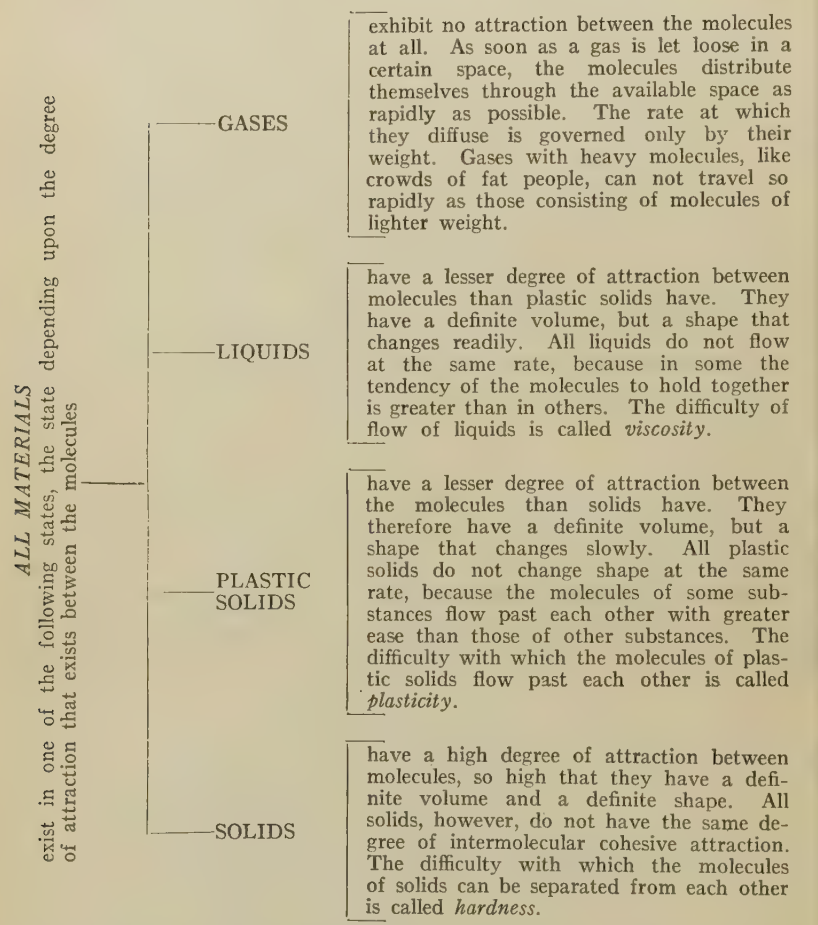
Whether a substance is a gas, a liquid, a plastic solid, or a solid depends upon two things—the distance between the molecules in the substance, and their rate of motion. The outline on the next page shows that the state of a substance depends upon its intermolecular cohesive attraction.

CHANGING STATE

The difference between solids, liquids, and gases is one of energy. There is reason to believe that all substances except those which decompose chemically without much difficulty may be changed from one state to another by having their molecules brought closer together or farther apart, as the case may be. If we heat a solid, we endow the molecules with more energy than they possessed previously. Thus they wander farther apart until they reach a point at which they no longer have sufficient intermolecular force to counterbalance this

outward pull and to keep them in a rigid condition. In other words, melting takes place.

If we continue heating the liquid, the molecules finally gain sufficient energy to give them power to dart off in all direc-


ALL MATERIALS
exist in one of the following states, the state depending upon the degree of attraction that exists between the molecules
GASES
exhibit no attraction between the molecules at all. As soon as a gas is let loose in a certain space, the molecules distribute themselves through the available space as rapidly as possible. The rate at which they diffuse is governed only by their weight. Gases with heavy molecules, like crowds of fat people, can not travel so rapidly as those consisting of molecules of lighter weight.
LIQUIDS
have a lesser degree of attraction between molecules than plastic solids have. They have a definite volume, but a shape that changes readily. All liquids do not flow at the same rate, because in some the tendency of the molecules to hold together is greater than in others. The difficulty of flow of liquids is called viscosity.
PLASTIC SOLIDS
have a lesser degree of attraction between the molecules than solids have. They therefore have a definite volume, but a shape that changes slowly. All plastic solids do not change shape at the same rate, because the molecules of some substances flow past each other with greater ease than those of other substances. The difficulty with which the molecules of plastic solids flow past each other is called plasticity.
SOLIDS
have a high degree of attraction between molecules, so high that they have a definite volume and a definite shape. All solids, however, do not have the same degree of intermolecular cohesive attraction. The difficulty with which the molecules of solids can be separated from each other is called hardness.

tions, showing no further attraction for other molecules of the same kind. Speaking unscientifically, the liquid boils.

If we apply pressure and lower the temperature on gases sufficiently, we can reduce them in turn to liquids and to solids.

For every gas there is a temperature above which the molecules move with such force that it cannot be liquefied, no matter what pressure is applied to it. This is called the *critical temperature* of this particular gas. The pressure needed to liquefy the gas at its critical temperature is called the *critical*

Courtesy Air Reduction Company

DRASTIC METHODS ARE NEEDED TO MASH THESE POTATOES

The terms *hot* and *cold*, after all, are relative, as may be seen in the pan of liquid air boiling vigorously over a piece of ice. The potatoes which have been immersed in liquid air need no explanation.

pressure of the gas. The farther the temperature of a gas is brought below the critical point, the less the pressure needed to liquefy it.

LIQUID AIR

Air, like all other gases, may be liquefied by subjecting it both to low temperatures and extreme pressures. To liquefy

air, purified gaseous air is passed through a series of coils so arranged that one set is wound concentrically around another set. The gas in the outer set is allowed to expand, thus cooling that in the inner set, since expansion of gases is a heat-absorbing process. This same air is circulated until the temperature is sufficiently reduced to liquefy it.

The terms *hot* and *cold* are relative. Liquid air is so cold that a piece of ice dropped into it acts like a red-hot iron plunged into a bucket of cold water. Metals plunged into liquid air lose their physical characteristics and become very brittle and sometimes granular. Fruit, vegetables, and flowers when placed in this liquid become frozen so rigidly that they can be reduced to a powder by a single blow of a hammer. Liquid air changes back to a gas at about 90 degrees below zero, Fahrenheit.

WHY WE BREATHE

But back again to breathing. It is extremely convenient that air is a gas, because breathing would be difficult and complicated otherwise. When a person breathes, air is taken into the lungs. The oxygen then passes through the walls of the tiny capillaries that line each cell of the lungs, and comes into the blood stream in this way. Here it forms some sort of a temporary chemical union with the red blood corpuscles. It is transported in this way to the various parts of the body, where it oxidizes the fuels stored up for this purpose. The products formed as a result of this chemical reaction—carbon dioxide and moisture—are carried by the blood stream back to the lungs where they are eliminated in the respired air. This simple chemical reaction, producing as it does two waste products which are eliminated as fast as formed, is important because it generates chemical energy. This energy makes it possible for us to run, jump, blow our noses, drive our cars, and even wink our eyes.

THE HEAVIEST OXYGEN CONSUMERS

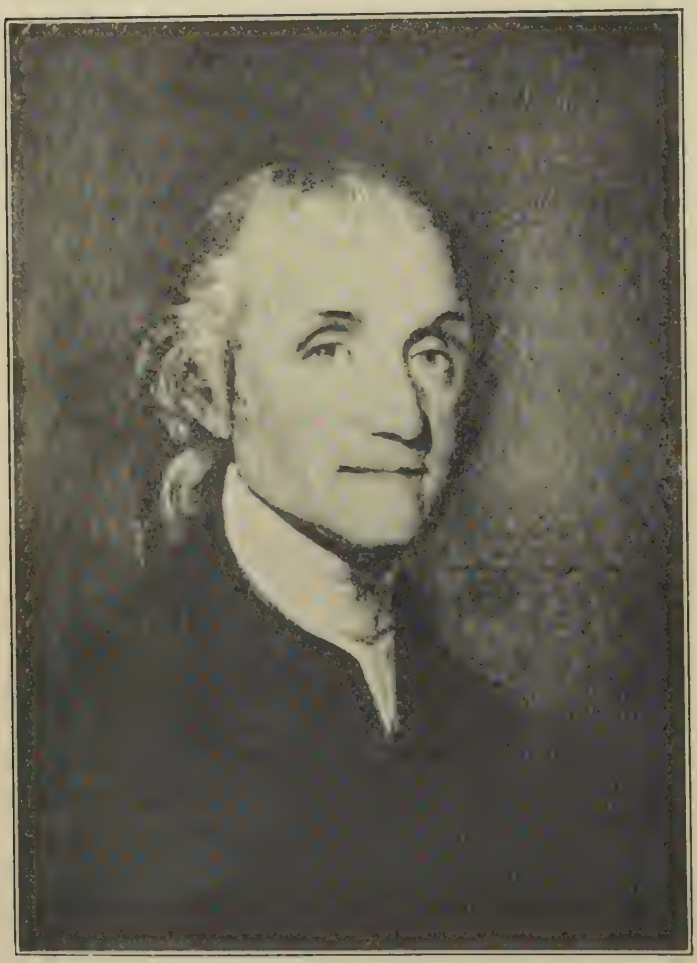
We may consider that we of the great human species are extremely energetic; but bees, flies, dogs, and chickens utilize more oxygen in proportion to their weight than we do. This means one of two things—either that these animals work harder than we do, or that they burn up a great deal of energy unnecessarily. The figures given below, as presented by Marre Parhon, a French investigator, give the cubic centimeters of oxygen consumed for each kilogram weight of the animal. Of course it will take a large number of bees to weigh 1 kilogram (2.2 pounds).

	Cubic Centimeters of Oxygen
Bees	17,336
Flies	6,709
Dog	911
Chicken	740
Man	233
Lizard	134
Frog	70
Carp	55
Crab	38
Starfish	32

THE DISCOVERY OF OXYGEN

The discovery of oxygen is attributed to Joseph Priestley, an English theologian and scientist, who on August 1, 1774, first prepared this gas. Priestley did not use air as his source of oxygen. He produced the gas by heating mercuric oxide, a compound of mercury and oxygen, by concentrating the sun's rays on the substance by means of a reading lens.

Two centuries before Priestley's time, Hieronymus Cardanus of Italy, who lived from 1501 to 1578, obtained a substance by heating saltpeter which he found to "nourish flame and relight bodies." He did not investigate its properties, however,



JOSEPH PRIESTLEY

or record the details of its preparation. About two years before Priestley made his discovery, Scheele, a Swedish apothecary, prepared the gas; but Scheele failed to publish any of his results until three years after Priestley's papers were in print, and priority in discovery is considered to mean priority in publication.

As soon as Priestley prepared this extraordinary gas, he began a careful study of its characteristics, although he was not aware of its nature.

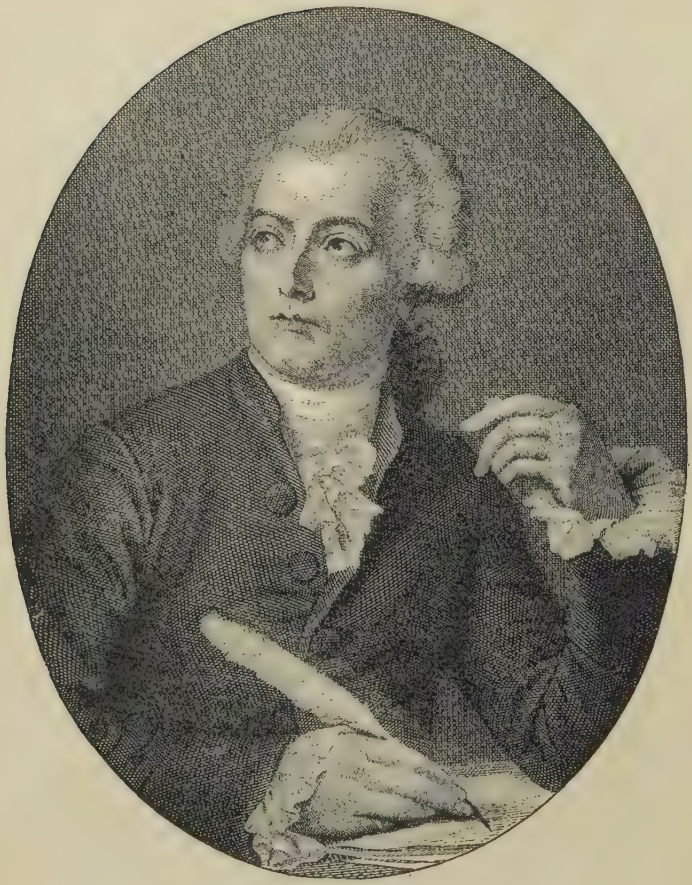
THE THEORY OF COMBUSTION IN PRIESTLEY'S TIME

Priestley's name for oxygen, *dephlogisticated air,* is worthy of comment. At the time when he lived, a peculiar theory of combustion was prevalent. It was thought that inflammable substances all had one thing in common, that is, that all of them contained a fanciful substance which scientists called *phlogiston.* When a substance burned, it was thought that the phlogiston separated from it and went up in smoke. Air was thought to have little phlogiston in it, but to be avid for more. Substances were therefore able to burn in air, according to the theory, because air would take up the phlogiston which the burning substance was giving off.

When a new substance was found which supported combustion more vigorously than air, Priestley called it dephlogisticated air, or air that was absolutely devoid of phlogiston.

It remained for Antoine Laurent Lavoisier, a French chemist who was a victim of the French Revolution, to propose the correct explanation of the rôle of oxygen in combustion. Lavoisier used quantitative methods in dealing with chemical changes, and was therefore the father of modern chemistry. Lavoisier discovered that if all the products formed when any substance burns are collected and weighed, the substance actually gains in weight. He therefore decided that a substance during burning actually combines chemically with the part of the air that he named *oxygen.*

Oxygen was named by Lavoisier in 1777, three years after its discovery by Priestley. Even this name was coined as a result of an erroneous idea which this scientist had, but the name stuck anyway. Lavoisier's French word *oxygène* meant spirit or principle of acids. He coined this word because he



LAVOISIER

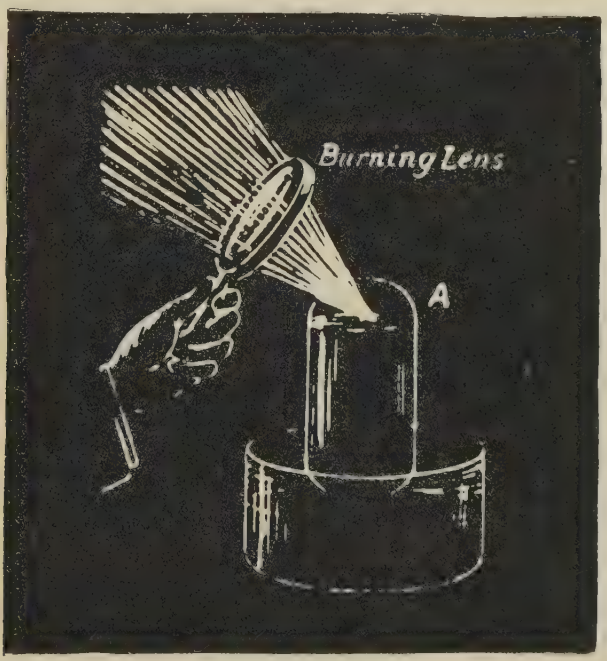
This scientist introduced quantitative measurements into the study of stuff and its behavior.

thought that this element was a necessary constituent of all acids. This has since been proved untrue.

PRIESTLEY'S OWN VERSION OF THE DISCOVERY OF OXYGEN

Priestley published a treatise in 1775 entitled *From Experiments and Observations on Different Kinds of Air.* His use

of the word *air* in this connection goes back to the time when the word was used to mean "gas." In this writing Priestley tells of his discovery of oxygen—or, as he called it, of dephlogisticated air. Quotations from his work will give something of his own enthusiasm:



PRIESTLEY'S LENS

The great scientist used this lens to concentrate the sun's rays as a source of heat in his various experiments.

For my own part [wrote Priestley], I will frankly acknowledge that, at the commencement of the experiments recited in this section, I was so far from having formed any hypothesis that led to the discoveries I made in pursuing them, that they would have appeared very improbable to me had I been told of them; and when the decisive facts did at length obtrude themselves upon my notice, it was very slowly, and with great hesitation, that I yielded to the evidence of my senses. And yet, when I reconsider the matter, and compare my last discoveries relating to the constitution

of the atmosphere with the first, I see the closest and easiest connection in the world between them, so as to wonder that I should not have been led immediately from the one to the other. That this was not the case, I attribute to the force of prejudice, which, unknown to ourselves, biases not only our judgments, properly so called, but even the perceptions of our senses; for we may take a maxim so strongly for granted, that the plainest evidence of sense will not entirely change, and often hardly modify our persuasions; and the more ingenious a man is, the more effectually he is entangled in his errors; his ingenuity only helping him to deceive himself, by evading the force of truth. . . .

Having procured a lens of twelve inches diameter, and twenty inches focal distance, I proceeded with great alacrity to examine, by the help of it, what kind of air a great variety of substances, natural and fictitious, would yield, putting them into vessels which I filled with quicksilver, and kept inverted in a bason of the same. Mr. Warltire, a good chymist, and lecturer in natural philosophy, happening to be at that time in Calne, I explained my views to him, and was furnished by him with many substances, which I could not otherwise have procured.

With this apparatus, after a variety of other experiments, an account of which will be found in its proper place, on the 1st of August, 1774, I endeavored to extract air from mercurius calcinatus [mercuric oxide] . . . and I presently found that, by means of this lens, air was expelled from it very readily. Having got about three or four times as much as the bulk of my materials I admitted water to it, and found that it was not imbibed by it. But what surprised me more than I can well express, was, that a candle burned in this air with a remarkably vigorous flame. . . .

Priestley thereupon tried other samples of this same material, with the same results.

This experiment might have satisfied any moderate sceptic [he continued], but, however, being in Paris in the October following, and knowing that there were several very eminent chymists in that place, I did not omit the opportunity, by means of my friend, Mr. Magellan, to get an ounce of mercurius calcinatus prepared by Mr. Cadet, of the genuineness of which there could not possibly be any suspicion; and at the same time, I frequently mentioned my surprise at the kind of air which I had got from this prepara-

tion to Mr. Lavoisier, Mr. Le Roy, and several other philosophers who honored me with their notice in that city; and who, I daresay, cannot fail to recollect the circumstance. . . .

Presently after my return from abroad, I went to work upon the mercurius calcinatus which I had procured from Mr. Cadet; and with a very moderate degree of heat, I got from an ounce of it, an ounce-measure of air. . . .

In ignorance of the real nature of this kind of air, I continued from this time (November) to the 1st of March following. . . . Till this first of March, 1775, I had . . . little suspicion of the air from mercurius calcinatus being wholesome. . . . I particularly remember telling Dr. Price that I was myself perfectly satisfied of its being common air; . . . though for the satisfaction of others, I wanted a mouse to make the proof quite complete.

On the 8th of this month I procured a mouse, and put it into a glass vessel, containing two-ounce measures of the air from mercurius calcinatus. Had it been common air, a full-grown mouse, as it was, would have lived in it about a quarter of an hour. In this air, however, my mouse lived a full half hour; and though it was taken out seemingly dead, it appeared to have been only exceedingly chilled; for, upon being held to the fire, it presently revived, and appeared not to have received any harm from the treatment. . . .

For my further satisfaction I procured another mouse, and putting it into less than two-ounce measures of air extracted from mercurius calcinatus . . . it lived three quarters of an hour. . . .

The dipping of a lighted candle into a jar filled with dephlogisticated air is alone a very beautiful experiment. The strength and vitality of the flame is striking, and the heat produced by the flame in these circumstances is also remarkably great. . . .

Nothing, however, would be easier than to augment the force of fire to a prodigious degree, by blowing it with dephlogisticated air instead of common air. This I have tried, in the presence of my friend, Mr. Magellan, by filling a bladder with it, and puffing it, through a small glass tube, upon a piece of lighted wood.

Possibly much greater things might be effected by chymists, in a variety of respects, with the prodigious heat which this air may be the means of affording them. I had no sooner mentioned the discovery of this kind of air to my friend Mr. Michell, than this use of it occurred to him. He observed that possibly platina might be melted by means of it.

From the greater strength of vivacity of the flame of a candle in this pure air, it may be conjectured that it might be peculiarly salutary to the lungs in certain morbid cases, when the common air would not be sufficient to carry off the phlogistic putrid effluvium fast enough. But, perhaps, we may also infer from these experiments, that though pure dephlogisticated air might be very useful as a medicine, it might not be so proper for us in the usual healthy state of the body: for, as a candle burns out much faster in dephlogisticated than in common air, so we might, as may be said, live out too fast, and the animal powers be too soon exhausted in this pure kind of air. A moralist, at least, may say that the air which nature has provided for us is as good as we deserve.

My reader will not wonder, that, after having ascertained the superior goodness of dephlogisticated air by mice living in it, and the other tests above mentioned, I should have the curiosity to taste it myself. I have gratified that curiosity, by breathing it, drawing it through a glass-syphon, and, by this means, I reduced a large jar full of it to the standard of common air. The feeling of it to my lungs was not sensibly different from that of common air; but I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but that, in time, this pure air may become a fashionable article in luxury. Hitherto only two mice and myself have had the privilege of breathing it.

JOSEPH PRIESTLEY

Joseph Priestley, the discoverer of oxygen, was born in 1733 in an English hamlet, Fieldhead, in Yorkshire. He was the oldest of six children. His father, a woolen cloth dresser, was only in moderate circumstances, and his mother died when he was six years old. He was then taken to live with an aunt who had married a man of some means. This aunt sent him to a grammar school, where he studied Latin, Greek, and other classical and academic subjects. During holidays he was tutored in Hebrew by Mr. Kirkby, a neighboring minister.

From the age of sixteen to twenty Priestley's health was so bad that he did not attend school or college, but studied lan-

guages at home. In 1752 his health was improved, and he went to Daventry to attend a nonconformist academy. He finished his ministerial studies there three years later, and was appointed to preach to a small congregation in Suffolk. From that time until 1791 he preached at various churches, attended chemistry lectures at various colleges, carried on experiments in his own home, and wrote many religious and scientific books.

In 1762 Priestley married Anne, the daughter of Isaac Wilkinson, a Wrexham ironmaster.

Priestley was made a fellow of the Royal Society of England in 1766, and in 1772 he was chosen a foreign associate of the French Academy of Sciences. He was personally acquainted with such men as James Watt, Matthew Boulton, Erasmus Darwin, Josiah Wedgwood, and Lavoisier. He met Benjamin Franklin during Franklin's visit to England.

In 1791 Priestley's house and belongings at Fair Hill, near Birmingham, were destroyed by a crazed mob. The anger of the mob was directed against Priestley because of his liberal religious and political views, and it burst forth in all its fury on the occasion of a dinner celebrating the fall of the Bastille, with which Priestley had nothing whatever to do. The dinner was planned for the evening of July 14, the anniversary of the fall of the Bastille, by a number of citizens of Birmingham who were interested in bringing about an improvement of the English constitution, a cause in which every thinking Englishman of the time was interested. Since Priestley had come to have the reputation of being an arch-heretic because of his nonconformist religious views, his name was bandied about as the leader in a political uprising which the dinner was said to portend.

Eighty-one law-abiding citizens of the vicinity attended the dinner, and dispersed early without the least disturbance. A considerable crowd had gathered around the hotel some time later in the evening, and Dr. Priestley's name was called loudly from time to time. The crowd grew larger as the evening

advanced, and finally a cry of "Church and King!" was raised. At that, all of the windows in the hotel were broken, although all of the dinner guests had previously departed. The crowd then proceeded to Fair Hill and fired Priestley's church. Dr. Priestley was warned of the approaching mob by a man who drove him and Mrs. Priestley to the home of friends. A son, William Priestley, remained at the home with a servant to attempt to save books and scientific equipment, but the mob came too quickly, and persuasion on the part of friends of the scientist was without avail.

The riot continued for several days before officers of the law arrived from London to quell it. During this time the homes of a number of Priestley's friends were burned, as well as other nonconformist meeting houses. Meanwhile Dr. and Mrs. Priestley traveled to London at the urgent advice of their friends.

Upon his arrival in London Priestley wrote a letter to "My Late Townsmen and Neighbors." In this he explained to them that they had been misled in the whole affair, that he had had no part in planning the dinner at the hotel, and that those who had attended the dinner had done so solely to express their joy at the emancipation of a neighboring nation. He expressed the friendliest of feelings toward the community and only showed chagrin in a paragraph in which he mentions the loss of his treasures:

> You have destroyed the most truly valuable and useful apparatus of philosophical instruments that perhaps any individual in this or any other country was ever possessed of, in my use of which I annually spent large sums, with no pecuniary view whatever, but only in the advancement of science, for the benefit of my country and of mankind. You have destroyed a library corresponding to that apparatus which no money can repurchase except in a course of time. But what I feel far more, you have destroyed *manuscripts* which have been the result of the laborious study of many years, and which I shall never be able to recompose, and this has been done to one who never did, or imagined you, any harm.

In 1794 Priestley decided to follow his three sons, who had emigrated to America the previous year. After landing in this country, he spent a short time with some of the noted scientists of New York and Philadelphia, but he decided to go further into the country to build his home. He found a quiet and picturesque spot in Northumberland, Pennsylvania, on the Susquehanna River, where he built a house and spent the rest of his life. He was twice tempted to leave and become a member of a university staff, once at the University of Pennsylvania and again at the University of Virginia. He declined both offers, however, because he did not wish to move from his home, and he considered the task of journeying either to Philadelphia or to Charlottesville, Virginia, for a course of lectures during each winter too arduous an undertaking. The invitation to the latter place came from Thomas Jefferson, founder of the University of Virginia. Jefferson was so much admired by Priestley that the scientist penned the following statement shortly before his death in 1804:

> Tell Mr. Jefferson that I think myself happy to have lived so long under his excellent administration, and that I have a prospect of dying in it. It is, I am confident, the best on the face of the earth, and yet I hope to rise to something more excellent still.

PRIESTLEY'S AMERICAN HOME

During the first year of Priestley's stay in America, little was done toward building his house because of the wet and "unhealthy" weather. It was almost two years later that Priestley finished the frame house which still stands in the same spot in this quiet Pennsylvania town, Northumberland. His wife died one year before the house was finished, and was buried in the Northumberland cemetery.

The house was remarkably well built, three stories in height in the main part, with a one-story laboratory at one end and a one-story kitchen at the other. The house has been changed

PRIESTLEY'S HOME AT NORTHUMBERLAND, PENNSYLVANIA

Above, the front of the house, from an old print. The laboratory is at the left, the kitchen at the right. Below, the rear of the house facing the Susquehanna River, from a recent photograph. No change has been made except the removal of the rail from the roof.

in almost no detail since the death of the great scientist in 1804.

Priestley's house became the property of the chemistry department of the Pennsylvania State College in 1919, when Dean George Gilbert Pond bought it at auction.

Since Dean Pond's death in 1920 a fireproof museum has been built on the lawn of the Priestley homestead as a repository for all of the books and pieces of apparatus, which could be collected, belonging to this scientist. A board of trustees composed of appointees of the Pennsylvania State College, the American Chemical Society, the American Philosophical Society, and the Pennsylvania Historical Society are now vested with the title to the Priestley property.

PILGRIMAGE TO PRIESTLEY HOUSE

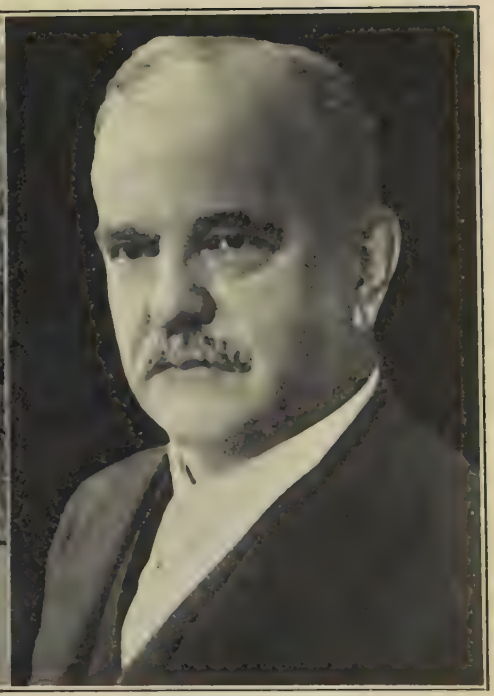
A pilgrimage of chemists from all over the world was made to the home and grave of Joseph Priestley at Northumberland, Pennsylvania, on Sunday, September 5, 1926. The occasion for the pilgrimage was the dedication of the museum on the corner of the lawn of the Priestley home. Mrs. Frances Priestley Forsythe, great-granddaughter of the scientist, was hostess to the visitors. Joseph Priestley, a great-great-grandson of the discoverer of oxygen, a student of medicine at the University of Pennsylvania at the time, was also present. About thirty-five other descendants of Priestley from many parts of the country were gathered together on this memorable occasion.

Mrs. Helen Palmer Pond, wife of the late George Gilbert Pond of the Pennsylvania State College, who was responsible for the preservation of the Priestley house, was among the guests of honor at the gathering.

During the morning, a special train reached Northumberland, bearing about two hundred chemists. These proceeded to Priestley's grave in the town cemetery. Priestley, his wife,

THE POND MEMORIAL

This fireproof room was built on the Priestley lawn to preserve the books and apparatus of the great scientist.



GEORGE GILBERT POND

Mr. Pond bought the Priestley house at auction and preserved it as a sanctuary for American chemists.

and seventeen descendants are buried there. Each visitor laid a rose on the grave, after which all went to the Priestley mansion. The visiting chemists were joined at the house by a large number of Northumberland townspeople and other friends of the Priestley family. A simple memorial ceremony was then held on the lawn.

Those attending the memorial exercises were reminded that in 1874 a much smaller group of American chemists had gathered at the same spot to commemorate the 100th anniversary of the discovery of oxygen. It was through correspondence following this gathering that the American Chemical Society was founded, the first meeting being held April 6, 1876.

COMMERCIAL USES OF OXYGEN

In addition to the oxygen that we breathe each moment as a part of the air, which costs us nothing, oxygen is now secured from the air and from water (where it is found also) as a common article of everyday use, as Priestley predicted. It is a matter of interest that every possible use of oxygen which Priestley mentioned in his first paper has since become common.

The commercial production of this colorless, odorless gas called oxygen has grown from nothing at all to well over a billion cubic feet a year. The rectifying of liquid air and the electrolytic decomposition of water are the methods now employed almost exclusively in its manufacture. The former process consists of liquefying air (which is a mixture), and then allowing the oxygen and nitrogen to boil off at their respective boiling temperatures. The latter process consists of passing an electric current through water, to which some acid has been added to make it a conductor. The hydrogen being charged with positive electricity is discharged at the negative pole. The oxygen, on the other hand, comes off at the positive pole. The choice between these two methods de-

Courtesy of Committee on Public Information

CUTTING STEEL WITH THE OXY-ACETYLENE TORCH

pends upon the availability of electric power, the facilities for disposing of the by-product, and other factors peculiar to each particular plant engaged in making this gas.

By far the greatest amount of oxygen made commercially is used in the welding and cutting of metals in so-called oxygen blowpipe work. There are, nevertheless, a number of other uses of this gas which are important. Oxygen is employed in the manufacture of oils used in painting. It is used

also in the oxygen method of removing carbon from automobile cylinders.

Small tanks of compressed oxygen are carried in dirigibles and airplanes for the use of passengers who may find it difficult to breathe at high altitudes.

Submarines always carry a large quantity of oxygen for use in respiration when it is necessary to remain submerged for a long time. In an emergency of this sort, the same air is used over and over again by passing it through liquids which remove the carbon dioxide, and then adding the proper amount of oxygen to it.

Oxygen is frequently used by mine rescue workers and firemen. It is used also for the resuscitation of persons whose

Courtesy U. S. Bureau of Mines

MINE RESCUE WORKERS

These men now take their oxygen with them. The oxygen masks they are wearing shield them from poisonous gases.

respiration is impaired through shock, asphyxiation, or partial drowning. It is used in medicine in the treatment of patients suffering from lung disorders.

A great deal of oxygen is used at the present time in metallurgical processes, as, for example, in burning out and cleaning stopped-up tap holes in steel furnaces. There are a number of other processes connected with ore-roasting and steel-tempering where oxygen is either substituted for air entirely, or is mixed with air in certain proportions so as to enrich it.

Liquid oxygen may be used as a blasting agent. Experiments carried out a few years ago at the hydroelectric works at Lochaber, Scotland, showed that it gave very satisfactory results for this purpose. Liquid oxygen-containing explosives are now a common article of sale for many purposes.

An interesting use quite remote from that of blasting is the use of oxygen in transporting live fish. Although a fish lives in water, it breathes the air that is absorbed in the water. During a trip of some length, the depleted air supply must be restored. Trials have shown that the bubbling of a slow stream of oxygen into the water tank is an excellent means of keeping fish alive and well under this circumstance.

OXYGEN TABOO IN ATHLETICS

There have been cases in the past in which athletes were given doses of undiluted oxygen to stimulate them to outdistance their opponents. Such oxygen-made records, however, will not stand in the estimation of true sportsmen, because they were not made under the conditions with which human life must ordinarily cope. Moreover, such a practice must invariably have bad after-effects, since pure oxygen is irritating and conducive to heart trouble. In other words, Priestley was right when he said that human beings might "live out too fast" if they breathed this gas too frequently.

Those who have breathed pure oxygen say that it gives one a temporary feeling of great exhilaration, followed by that of exhaustion. The reason for this is obvious. When we take oxygen into our lungs, it is carried by the blood to the various

muscle tissues of the body, where it combines chemically with stored up fuel for the formation of heat and energy. If one breathes pure oxygen, therefore, oxidation goes on very rapidly, and uses up great quantities of energy-supplying materials in our tissues.

NITROGEN

Because oxygen is such an active substance, nature has provided that about four-fifths of the volume of air consist of an inactive gas called nitrogen. The presence of nitrogen as a diluent of the oxygen of the air keeps us from burning up our fuel supply more rapidly than our digestive systems could replace it.

So far as our breathing is concerned, nitrogen serves only to dilute the oxygen of air. But aside from this it is quite important on its own account. "Nitrogen is used in vast quantities for two diametrically opposed purposes—to nourish us, and to kill us," says one writer. As a plant food, nitrogen is absolutely essential. In explosives such as gunpowder, nitroglycerine, T N T, and dynamite, it is likewise an indispensable constituent. Although explosives are generally thought of in connection with war, they are of considerably more importance in times of peace, however, to assist in mining, building, and similar pursuits.

The first attention paid to nitrogen was to notice that after the respirable portion of air had been used up by animals confined in a closed space, the gas left would not support life. This discovery was made by Rutherford. The remaining gas was therefore first named *azote,* or "without life." Priestley was probably the first person to prepare nitrogen from its compounds.

Lavoisier was the first scientist to study extensively the properties of nitrogen. He was also the one who coined the word *nitrogen.* The name means "material of nitre." Nitre

is a compound which the chemist calls potassium nitrate, and which was an early laboratory source of this gas.

NITRATES IN NATURE

Nitrates are formed naturally in the soil by the action of microörganisms which convert the nitrogen of air into its compounds. One type of these microörganisms lives in nodules or lumps on the roots of such plants as clover, peas, and beans. These organisms take nitrogen from the air which is always present in loose soil, and convert it into nitrates. The nitrates formed are used directly by the plants on the roots of which the bacteria live. The plants convert nitrates into elaborate nitrogen-containing organic compounds called proteins, and utilize these in building up new plant tissues.

When all or a part of the plant is plowed under the following season, microörganisms of another type change the plant protein back into nitrates again. These nitrates remain in the soil until another crop of plants utilizes them again as plant food.

The quantity of nitrates stored in one place in the soil does not become very great for several reasons. One of these is the fact that some plant or other, either a cultivated product or a weed, comes along and uses up the supply about as fast as it is deposited. The chief reason, however, is the fact that nitrates dissolve in water and are thus washed away.

THE CHILE NITRATE BEDS

In spite of the solubility of nitrates in water, a few parts of the earth have large deposits of nitrates in them. The most notable of these is to be found in the great desert of northern Chile, in a narrow strip of about four hundred and fifty miles in length. This region furnishes the chief supply of natural nitrate in use in the world to-day. The origin of the Chilean

nitrate beds is discussed as follows by Enrique Cuevas, Counselor of the Chilean Embassy to the United States, in an article on "The Nitrate Industry":

This is a mooted question on which no two geologists agree. There are, however, some theories which are generally accepted as more or less correct. One is that in prehistoric times the entire nitrate zone was a part of the Pacific Ocean, and that through volcanic disturbances that portion of the sea was cut off and the water evaporated by a very slow process. Fish skeletons found in the *caliche* furnish good proof of this assertion, as does the fact that the Pacific coast is rising gradually. This theory is, however, contradicted by the fact that no bromine exists there—a substance naturally looked for in deposits thus formed.

Another theory attributes the origin of the *caliche* to an electrical process. The passage of an electric spark through the moist air produces a combination of nitrogen and oxygen resulting in nitric acid. Electrical storms—a frequent occurrence in the Andes—may have acted in this way and formed great quantities of nitric acid. The water, charged with the acid, coming into contact with the lime in the rocks, may have produced nitrate of lime, which together with sulfate of soda, may in turn have formed nitrate of soda, freeing the sulfate of lime.

A later theory maintains that the deposits are an accumulation of land drainage brought down through ages from the highlands along the coast.

Others explain the formation as the work of microbes, or as the result of the action of volcanoes discharging through their craters ammonia-charged steam there condensed.

FIXING NITROGEN

The newspapers sometimes talk about "fixing" juries, and judges, and congressmen. The chemist, who is not concerned with this sort of thing, has been working for years on the "fixing" of nitrogen. The word *fix* is legitimately used in this connection, and will be found in the dictionary to mean the converting of a gaseous substance into a solid compound.

During comparatively recent times the supply of nitrate

Courtesy Ingersoll-Rand Co.
Courtesy Synthetic Nitrogen Products Corp.

NATURE AND THE CHEMIST COMPETE IN THE NITROGEN MARKET

Above, sodium nitrate from the great Chile saltpeter beds, ready for shipping; below, the Leuna works at Merseburg, Germany, the world's largest nitrogen fixation plant.

from natural beds has become inadequate for the growing needs of nitrogen compounds. When this fact became known, the chemist set himself to the task of increasing nature's supply by the production of nitrogen compounds artificially.

The air above one square mile of the earth's surface contains 20,000,000 tons of the element nitrogen. The earth's surface has an area of over 200,000,000 square miles. The possibilities of the atmosphere as a source of free nitrogen therefore are practically limitless. The problem, however, is to get the nitrogen out of the air and fix it—that is, convert it into a compound that is usable for making fertilizers in time of peace, and explosives needed both for warfare and in many peaceful pursuits.

One of the earliest methods for the production of synthetic nitrogen compounds was worked out in Norway by Professor Kristian Birkeland and Engineer Samuel Eyde. The method which these scientists used was called the arc process, and it consisted of passing air through a powerful electric arc, in which the nitrogen and oxygen of the air combine chemically to form oxides of nitrogen. These oxides are then absorbed in water to form nitric acid, and in alkalies to form nitrates. This method is successful in Norway because the many waterfalls of that country provide a cheap source of electric energy.

The calcium cyanamide process of nitrogen fixation consists of isolating nitrogen from liquid air, made possible by the difference in its boiling temperature from that of oxygen, and then passing this nitrogen over highly heated calcium carbide made by fusing lime and coke in an electric furnace. The calcium cyanamide formed can be used directly as a fertilizer and indirectly in the chemical production of other nitrogen compounds.

By far the cheapest method of nitrogen fixation is the Haber-Bosch process. This consists of bringing hydrogen and nitrogen gases together under considerable pressure in the presence of a catalyst. The hydrogen used is obtained from water gas made by passing steam over heated coke. The nitrogen is derived from the air, but does not need to be separated from the air as in the cyanamide method. Whereas the cyanamide process requires from 10,000 to 12,000 kilowatt hours of elec-

trical energy for each ton of nitrogen produced, the Haber-Bosch method needs but 3,000 to 5,000 kilowatt hours.

The United States government maintains the Fixed Nitrogen Research Laboratories at Washington, D.C., to study the production of synthetic nitrogen compounds.

A VERBAL STRUGGLE FOR STUFF

In 1916 the United States Government realized the importance of nitrogen, and appropriated about $20,000,000 for the establishment of plants for the manufacture of nitrogenous products from the nitrogen of air. Plants were established at Sheffield, Alabama; Muscle Shoals, Alabama; Cincinnati and Toledo, Ohio; Saltville, Virginia; and Indian Head, Maryland. A total of $110,000,000 was spent at these plants on nitrogen production during the war period. At the close of the war, none of them had reached full production.

After the war, a debate of many years was waged in Congress and in the press over the disposition of Muscle Shoals, one of the largest of these nitrogen-producing plants. This was literally a verbal struggle for stuff.

FIVE RARE GASES IN AIR

Two English scientists, Lord Rayleigh and Professor William Ramsay, discovered in 1895 that a little over 1 per cent of the air had been hiding out from previous investigators. These gases, present in very small quantities, had defied detection; and analysts had attributed to experimental error the slight failure of their results, when added up, to equal 100 per cent.

The first gas that Rayleigh and Ramsay dragged into the open was named *argon* by the discoverers. They coined this name from the Greek word for *inert,* because the gas refused to combine chemically with any other substance. Its very

inertia, however, has since proved to be a blessing. It is used to fill ordinary electric light bulbs. Argon-filled bulbs give twelve times as much light for each kilowatt of current as the old carbon vacuum bulbs. Then, too, it was found quite recently that a mercury vapor lamp or tube would give a brilliant blue light if filled with argon, and this fact has revolutionized electric sign advertising.

During the same year, 1895, Ramsay and Rayleigh discovered the second of the atmospheric gases which had previously evaded the notice of the human race. This gas—helium—had previously been observed in the sun by means of a spectroscope, and had been named after that body. The helium which is now used in airships is obtained from special kinds of illuminating gas found in a few regions of this country. The air itself contains too small an amount of helium for practical uses.

Professor Ramsay, working with another English investigator, Travers, discovered the three other ingredients of air three years later. They named these gases neon, krypton, and xenon.

Neon, a gas which the discoverers named from a Greek word for "new," has recently come to be quite familiar to us in the brilliant red neon electric tubes which cry forth to the world the virtues of everything from aspirin to the name of the nearest beauty specialist.

Krypton, named after the Greek word for "hidden," and xenon, named from the Greek term for "stranger," have found no practical uses to date.

RAINBOW TUBES

Speaking of argon and neon electric tubes reminds one that a whole rainbow of beautiful colors can be obtained by the judicious use of these so-called rare gases in evacuated glass tubes through which an electric current is passed. A mercury

vapor tube produces a blue-violet light well known to those who have had their photographs taken at night in front of ocean waves painted on canvas at some seaside photograph gallery. If argon is introduced into the mercury tube, as mentioned above, a bright blue light results. If a mixture of argon, neon, and mercury is used, a brilliant white results. Argon and helium in a tube containing the same type of phosphorescent material used on radio dials gives green. Helium alone gives a ghostly white.

D. H. Killefer, in an article in *Industrial and Engineering Chemistry*, says:

> The most important feature of these tubes, although advertising signs loom larger from an economic standpoint, is the production by neon of a penetrating red light without the use of filters. For visibility under adverse conditions no light compares with red. It is less refracted by fog and mist and produces the most pronounced sensation on the human optical nerve.
>
> For this reason powerful neon lights are coming rapidly into use as beacons for airplanes and ships to guide them through fogs and inclement weather. Their importance to safe navigation and to the development of air transportation can hardly be overestimated. Beacons visible for fifty miles through a haze rendering ordinary lights of immense candlepower invisible within ten or twelve miles have been through the most severe tests and have proved of highest value.
>
> The comparatively low power consumption of these efficient light producers makes possible their use to outline landing fields for night flying in a completely unmistakable manner, and even hundreds of feet of luminous neon tubing can be operated for this purpose where needed.

ANALYSIS OF AIR

The analysis outlined below, made by Ramsay, gives some idea as to the small amount of these rare gases present in the air. When we look at this table, we are no longer surprised that scientists failed to detect these five rare constituents for so many years:

	Per Cent by Weight
Nitrogen	75.5
Oxygen	23.2
Argon	1.3
Carbon dioxide	.046 to .4
Krypton	.028
Xenon	.005
Neon	.00086
Helium	.000056

A WASTE PRODUCT OF THE AIR

Besides oxygen and nitrogen and the five rare inert gases, air contains from four one-hundredths to four-tenths of 1 per cent of carbon dioxide, a waste material. Carbon dioxide gets into the air by the breathing of animals and plants, the decay of organic materials, and the burning of carbon-containing fuels. The amount of it found in air would become much higher if it were not for the fact that plants use carbon dioxide as food.

Plants carry on two physiological processes, during which they take ingredients from the air. They breathe continuously, day and night, taking in oxygen and exhaling carbon dioxide. They also take in carbon dioxide during the day and combine this with water and materials which they obtain from the soil to form various food materials.

Since carbon dioxide can be made very cheaply by a number of commercial methods, it is not at present extracted from the air for the various industrial uses to which it is put.

FORCEFUL AIR

Any person who has had his hat lifted by the wind and carried up the street can testify that air is capable of moving with a great deal of violence. Although the molecules of the various gases which go to make up air are always moving to some extent, they sometimes rush around at unbelievable

speeds and develop winds or even tornadoes. The uneven heating of the air in various regions causes winds. When gases are heated, the molecules move farther apart, and the pressure per cubic foot becomes less. Air from heavier pressure areas then rushes in with more or less violence, depending upon the degree of difference of their respective pressures.

Photograph by Wide World Photos

AIR MOLECULES ON THE RAMPAGE

An approaching wind storm in western Oklahoma, as seen from a distance of two miles.

A "twister" is occasioned by one low pressure area becoming surrounded by high pressure areas. This causes an inrush of air from all sides at the same time.

The weight of air also makes it possible to sail air craft of all sorts, and to drop from a height by means of parachutes.

It would seem that air is of sufficient use to justify its exist-

ence if it simply served human beings as breathing stuff. But creative man has found other uses to which he can apply this valuable substance. He has found that if he confines air in a small space and puts pressure upon it, he can use it to bore holes through metal or stone, spread paint, cut glass, polish metals, run hammers, and fill automobile tires. A poet has mentioned but a few of its many virtues in the following two verses of limerick:

The air drill can make holes for bolts;
The air blast can save us from jolts.
And on concrete and gravel
Pneumatic tires travel!
There's now little need to raise colts.

The air-driven sand blast cuts glass,
And polishes cast iron and brass.
It makes the air hammer
To stutter and stammer;
There's no other stuff in its class.

A ROCK CRUSHER OF THE MIDDLE AGES RUN BY WATER POWER

It was not enough to use water for drinking and bathing purposes, but ancient man used it also to float ships, medieval man used it to do work, and modern man uses it for all of these purposes and many more. (Woodcut from Agricola, *De Re Metallica,* Book VIII.)

CHAPTER III

A DRINK OF WATER

And Isaac's servants digged in the valley, and found there a well of springing water. —GENESIS 26:19

WATER ranks next to air as man's most important material. A person can live longer without food than he can without water.

In the very earliest prehistoric times man drank whatever water he could find. Later he learned how to dig wells and secure water that was ordinarily hidden from view. The quotation at the head of this chapter tells of the efforts of Isaac to replace the wells which Abraham had built, but which the Philistines had filled with stones. The habit of ruining an enemy's water supply is an old one, for the importance of water has ever been recognized.

The Romans were the first of the ancient peoples to build elaborate water systems. When Rome was at its height, the inhabitants used 400,000,000 gallons of water a day for household purposes and for supplying their vast bathing establishments and numerous fountains. This water was conducted across the Campagna in fourteen aqueducts, which were marvels of engineering skill. The ruins of some of these aqueducts may be seen to-day.

CAMPERS FACE A WATER PROBLEM

The modern camper faces somewhat the same situation with regard to water as did ancient man. Going from place to place, taking whatever supply of water is to be found beside the road, one is certainly at the mercy of fate as to the conse-

quences. Frequently the consequences are serious, since many cases of typhoid are known to follow a summer outing.

The public health services of many states are coping with this problem by analyzing the water supplies along the highways and marking them as either safe or unsafe for drinking.

The importance of water is never felt more keenly than when it is hard to get. In the eastern part of the United States, where water is fairly plentiful, the inhabitants frequently fail to realize how carefully the Westerners treasure their water supply. Because of this difference, the average Californian uses less than half the amount of water that a resident of Chicago uses. Of course one does not really appreciate what a scarcity of water means until he crosses the Sahara Desert.

COMPOSITION OF WATER

Water is classed by the chemist as a compound, whereas air is a mixture. A mixture consists simply of various ingredients not combined chemically. A compound, however, is constituted of elements combined chemically and always in a definite proportion by weight.

Each molecule of water consists of two atoms of hydrogen and one of oxygen. Hydrogen and oxygen are two of the ninety-two elementary forms of matter of which everything is composed.

If an electric current is passed through water to which a little acid has been added, the water is decomposed into its two elements, both of which are gases at ordinary temperatures. This is one method of preparing these elements for industrial use, although oxygen is frequently prepared from the air, and hydrogen by other methods.

HISTORY OF HYDROGEN

We have noted in the previous chapter the history and some of the outstanding uses of oxygen. Hydrogen was discovered

eight years earlier, and has been found to have uses quite as interesting.

Paracelsus, an alchemist living in the sixteenth century, was the first writer to mention the fact that vinegar gave off a gas when in contact with iron. This scientist even discovered that the gas would burn, but he did not look on it as essentially different from other inflammable gases that he knew.

Henry Cavendish, an English investigator who lived from 1731 to 1810, was the first person to recognize hydrogen as a distinct substance, and to study its characteristics carefully. It was in 1766 that Cavendish first prepared and began his study of this gas. That year is therefore recorded as the date of the discovery of hydrogen. The name *hydrogen* was coined a few years later by Lavoisier. Cavendish called the gas inflammable air, and both he and other scientists of his day thought that it was probably the same substance as phlogiston, the mythical material that was supposed to confer inflammability upon anything that contained it.

HENRY CAVENDISH

The Honorable Henry Cavendish, discoverer of hydrogen, was the eldest son of Lord Charles Cavendish and the nephew of the third duke of Devonshire. His mother, Lady Anne Grey, was the daughter of the Duke of Kent. Although Cavendish inherited a large patrimony, he adhered to an extremely severe mode of living. His two chief interests seem to have been to carry on scientific investigations and to avoid the society of his fellows. He ordered his dinner each day by placing a note on the hall table. His women servants were ordered to keep out of sight on threat of dismissal. He never married.

Cavendish's scientific work is distinguished for its exactness. He was thoroughly trained in mathematics, and was one of the few men of his time to apply exact measurements to the study

HENRY CAVENDISH, DISCOVERER OF HYDROGEN

of various substances. He was the first to determine the density of the gases known in his time, and also to find out the ratio by volume in which various gases combine to form new substances. He was the first to prove that hydrogen burns to form water. This, in addition to his discovery of hydrogen, contributed materially to early progress in chemistry. He also was the first scientist to do any correct thinking about the composition of air.

USES OF HYDROGEN

One of the chief uses of hydrogen is for filling balloons and dirigibles. The United States Navy now uses helium—which is non-inflammable, and which has 92 per cent the lifting power

Courtesy of the General Electric Co.

WELDING WITH THE ATOMIC HYDROGEN FLAME

Dr. Irving Langmuir of the General Electric Company discovered that if a small jet of hydrogen were directed against the electrodes of a tungsten arc, the hydrogen molecules would split into atoms with considerable absorption of heat. The atoms recombine to molecules just beyond the arc, and liberate about half again as much heat as is generated in the ordinary oxygen-hydrogen flame.

of hydrogen—for its larger dirigibles. For its balloons, however, it still employs the more plentiful hydrogen. Other countries are obliged to use hydrogen exclusively for their lighter-than-air craft, because no available helium to speak of has yet been found outside the United States.

Hydrogen was the original inflammable gas used in blowpipe work. The oxyhydrogen blowpipe produced temperatures previously undreamed of. This flame, when played against a lump of lime, also produced a bright incandescent light which was used for a time in stage lighting. This was the origin of the term *the limelight*.

The oxyhydrogen flame has been largely superseded by the oxyacetylene flame, except in some special processes, because the latter is much hotter and cheaper to produce.

Dr. Irving Langmuir, of the General Electric Company, has produced an atomic hydrogen flame which is playing an interesting part in certain high-temperature processes.

HYDROGENATION OF OILS

There has been a scarcity of solid fats in the world for some time. There has been a corresponding over-supply of liquid fats or oils. Unfortunately the solid fats are in greater demand than the liquid ones for cooking and for a variety of other purposes. The queer thing about the situation is that the chemical composition of all of these fats is quite similar. The only difference between them, in fact, is the amount of hydrogen which the molecule of each of them contains. Stearin, the fat of tallow, which is quite satisfactorily solid, consists of molecules that contain carbon, oxygen, and hydrogen. Olein, the fat of coconut, cottonseed, and a number of other oils, likewise contains these three elements. The proportion of carbon, oxygen, and hydrogen atoms in the molecule of these two compounds is this:

Stearin—carbon 54, oxygen 6, hydrogen 110
Olein—carbon 54, oxygen 6, hydrogen 104

In other words, the only chemical difference between the solid fat of cows, sheep, and pigs, and of various kinds of oils is a difference in hydrogen content.

This fact has been known by the chemist for some time.

But what to do about it was quite another story. The chemist has tried to force hydrogen to combine with oils by putting them under pressure, by heating them, by cooling them, and by almost every conceivable trick. But the oils remained consistently obdurate, and failed to unite chemically with any more hydrogen.

Finally it was discovered that if some metallic substance such as platinum or nickel were present, it would serve in some way to make the oil hook up chemically with additional hydrogen. Just what the metal does is an unanswered question, but it acts as a so-called catalyst or agent that brings about a chemical reaction without itself being any different in composition at the end of the process than it was at the beginning.

Oils with even less hydrogen per molecule than olein have also been successfully solidified by hydrogenation. Even fish oils, consisting largely of an oil called by the fanciful name of clupandonin, can be made to become hard by this process, although it has never yet been induced to abandon the odor that betrays its origin.

At the present time, more than 500,000,000 pounds of oil are hydrogenated annually in the United States by catalytic processes. This produces fat equal to that obtained from 7,000,000 hogs. A still greater quantity of fat not itself hydrogenated is modified to advantage by blending it with hydrogenated fats.

WATER AGAIN

When hydrogen is heated to the proper temperature, it unites violently with oxygen of the air. The product formed is water. It is this inclination to combine with oxygen which makes it explosive and unsafe for filling dirigibles.

If a slow stream of hydrogen burns quietly, it is also undergoing the same operation, combining chemically with oxygen with the production of water. This brings us back again to the original subject—water.

Man has been a hard taskmaster to the common substances he finds round about him which cost him nothing. Just as he puts air to work in various pneumatic appliances, so also has he harnessed water and made it serve him.

According to the United States Geographical Survey, this country has 40 per cent of the developed water power of the world, but only 6 per cent of the total potential power.

Courtesy Allis-Chalmers Mfg. Co.

A GLORIFICATION OF THE MEDIEVAL WATER WHEEL

A modern turbine runner, designed to utilize water power.

This survey gives us the following additional facts:

The leading states in developed water-power are New York—with 1,300,000 horse-power, and California, with 1,111,000. These states' totals compare favorably with those for some of the most progressive countries in water-power development in Europe, where France leads with 1,400,000 horse-power, Norway has 1,350,000 horse-power, Sweden, 1,200,000 horse-power, and Switzerland, 1,070,000 horse-power.

The largest percentage of power has been developed in the New England States, where the capacity of the water wheels installed is 1,381,000 horse-power and the estimated potential power at low water-storage is 868,000 horse-power.

In the Pacific Coast States—Washington, Oregon, and California —the capacity of water-wheels installed is 1,893,000 horse-power, and the potential power at low water without storage is 11,500,000 horse-power.

The largest water-power development in the world is at Niagara Falls, where the plants in operation have a capacity of 870,000 horse-power, of which 385,500 horse-power is on the United States side. The capacity of the plants at Niagara is being increased by 114,500 horse-power in the United States and 300,000 horse-power in Canada.

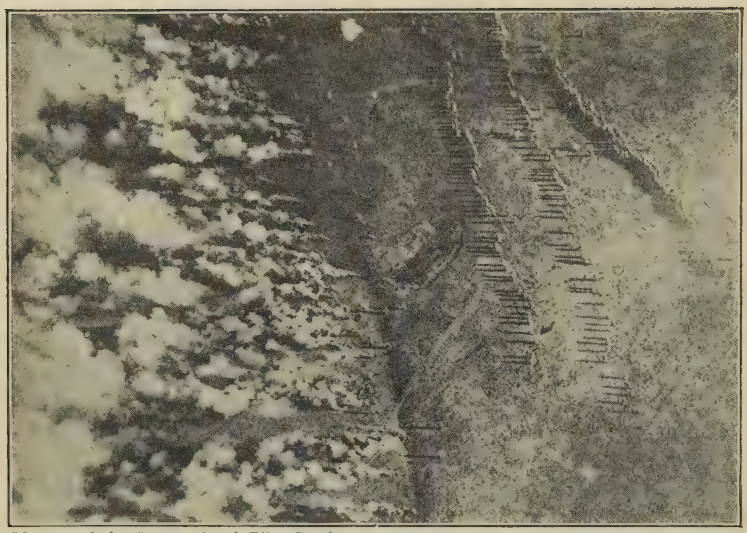
Other large plants are one of 170,000 horse-power on the Mississippi at Keokuk, Iowa, from which power is transmitted to St. Louis, and two plants aggregating 268,500 horse-power on St. Maurice River in Canada, from which power is transmitted to Montreal, Quebec, and other cities. Canada ranks next to the United States in water-power development, with 2,418,000 horse-power, or over 10 per cent of the world's total.

Europe has one-third of the developed water-power in the world. Two plants at Rjukan, in Norway, have a total capacity of 239,000 horse-power, and at Trollhattan Falls the Swedish Government has installed a plant of 155,000 horse-power. At Lake Fully in Switzerland, the remarkably high head of 5,413 feet is utilized. France, Italy, Germany, Norway, Sweden, and Switzerland have each developed more than 1,000,000 horse-power.

In Asia, Japan, with 1,000,000 horse-power, and India, with only 150,000 horse-power, are the foremost countries in water-power development.

New Zealand has developed only 45,000 horse-power, but is rapidly increasing this amount. Australia has practically no developed water-power. The island of Java has 56,000 horse-power developed or to be developed by plants under construction. Africa possesses only 11,000 horse-power of developed water-power.

The total potential water-power of the world is estimated at 439,000,000 horse-power at low water, of which 62,000,000 horse-power is in North America and 28,000,000 in the United States. Africa is richest in undeveloped water-power with 190,000,000 horse-power; Asia has 71,000,000 horse-power, South America, 54,000,000 horse-power, and Europe, 45,000,000 horse-power.



Photograph by International Film Service.

ONE OF THE HORRORS OF THE HALOGENS

Airplane photograph of a chlorine gas attack on the Russian front early in the World War.

CHAPTER IV

WONDERS AND HORRORS OF THE HALOGENS

There's a pale yellow gas that's called fluorine
That's chemically very alert;
And a greenish gold gas that's named chlorine,
With which no man wants to flirt.
And in the same family there's bromine
A volatile liquid brown-red;
And last but not least we have iodine
A black lustrous solid instead.

—ANONYMOUS

IN the earliest times, if the water supply became contaminated, a plague followed, which no one knew how to account for except to attribute it to some evil spirit. Later it was recognized that bad water caused disease, and precautions were taken to keep the water supply pure. But if, in spite of precautions, the water became bad, there was nothing to do about it except to hunt about for another supply.

THE BATTLE WITH WATER-BORNE DISEASE

Even after the establishment of the germ theory, in which the cause of typhoid fever and other water-borne diseases was revealed, some time elapsed before a means of coping successfully with impure water was discovered.

At the beginning of the twentieth century the sterilization of water was unheard of. In 1908 the polluted water stream at the Bubbly Creek filtration plant at Union Stock Yards in Chicago was chlorinated by the use of bleaching powder or chlorinated lime. Since that time sterilization of large water supplies (and even small ones if they are polluted) has come to be almost universal. Although a number of agents are employed, chlorinated lime and the element chlorine itself are the two most common disinfectants used to purify drinking water.

Chlorinated lime is a substance formed by saturating ordinary lime with chlorine gas. It decomposes, giving off chlorine gas when placed in water. The decomposition is more rapid if some acid is present. Since there are at least small amounts of dissolved carbon dioxide (carbonic acid gas) in all natural water supplies, chlorinated lime is made to give off its chlorine very easily when it is placed in the water. Chlorinated lime is shipped in drums made of wood or sheet iron.

Chlorine, when used as a water disinfectant, is compressed to a liquid and shipped in seamless steel cylinders holding 100 to 150 pounds each. The chlorine prepared for shipment in this way is 99.8 per cent pure.

Tests made on the comparative disinfectant values of chlorine and chlorinated lime, pound for pound, show that chlorine is five to ten times more effective. The chlorine likewise has the advantage of being able to be removed from the water after treatment by spraying the water into the air, a method of treatment called aëration. Chlorinated lime is not

only difficult to remove from water, except by processes too expensive for common use, but it also adds hardness to water because of its lime content. The chief feature that recommends chlorinated lime, on the other hand, is the fact that it is very cheap and easy to handle.

Comparative studies made in various cities before and after chlorination of the water supplies show that this method of water sterilization has practically wiped out water-borne diseases.

There are other sterilization agents applicable to water treatment which are just as effective as chlorine and chlorinated lime. Ozone is quite effective, and has the advantage over chlorine of adding no taste to the water. But the item of expense has, as yet, limited the use of ozone to only small supplies of water.

The chlorination of city water supplies is done in conjunction with other types of treatment. A muddy supply of water is usually allowed to settle in large basins (sometimes with the help of small amounts of lime and alum, or other coagulants) to remove the bulk of the clay or sand. It is then filtered through large sand filters. It is chlorinated just before going into the pure water reservoir.

WHAT SORT OF STUFF IS CHLORINE?

Chlorine is a greenish-yellow gas—heavy, stifling, irritating. It nevers occurs naturally, but may be made artificially by passing an electric current through a solution of common salt, or by giving various chlorine-containing compounds some chemical treatment or other. Many boys—girls, too, for that matter—who have their own laboratories at home, or who have become too inquisitive in the chemical laboratory at school, will long remember the head, throat, and lung irritation which they suffered for several days after breathing too large an amount of this stifling gas.

No better description of chlorine has ever been given than that recorded in 1774 by Karl Wilhelm Scheele, a Swedish scientist, when he discovered this gas. Scheele was placing two chemicals together for quite another purpose, when yellow fumes of a hitherto unknown stuff came off. This is the way he described his experiment:

In order clearly to apprehend this novelty [wrote Scheele] I took a retort containing a mixture of manganese [manganese dioxide] and acidum salis [hydrochloric acid]. In front of the neck, I bound a bladder emptied of air, and set the retort in hot sand. The bladder became distended by the effervescence in the retort. When the acid no longer effervesced, which was an indication of its saturation, I removed the bladder, and found that this air [gas] had colored it yellow, . . . it had, however, a quite characteristically suffocating smell which was most oppressive to the lungs. . . .

The corks in the bottles became yellow. . . .

Blue litmus paper became almost white; all vegetable flowers—red, blue and yellow—became white in a short time; the same thing also occurred with green plants. . . .

Iron filings were put in the same bottle and they dissolved. . . .

All metals were attacked. . . .

Insects immediately died in the vapors; and fire was immediately extinguished by them.

SCHEELE, A DISCOVERER OF NEW STUFF

Scheele was one of the most notable of the early discoverers of new materials. He undoubtedly prepared oxygen independently of Priestley, even before Priestley had done so, but he did not record his findings until after Priestley's papers were published, so nobody knew anything about it at the time. He discovered a long list of additional substances, the names of which are familiar only to a chemist.

He discovered hydrogen fluoride, molybdic, tungstic, arsenic, nitrosulphonic, lactic, gallic, pyrogallic, oxalic, citric, tartaric, malic, mucic, and uric acids. He isolated glycerin and milk sugar, and determined the nature of microcosmic salt, borax,

Prussian blue, baryta, and manganese. He was the first to prepare hydrocyanic acid, arsine, and the arsenical pigment called Scheele's green. He was the first to study the properties of hydrogen sulphide. He worked out the method still in use for the analytical separation of iron and manganese, and the decomposition of mineral silicates by fusion with alkaline carbonates.

The man who made all of these discoveries was born December 19, 1742, at Stralsund, the capital of Pomerania, which, though then included in the Kingdom of Sweden, at the present time constitutes part of the German Republic. Scheele's father was a merchant, and the boy who was destined to become one of the most famous chemists the world has ever produced was the seventh child of a family of eleven children. He does not appear to have distinguished himself at school, exhibiting no taste whatever for languages. Because there were no sciences taught in the schools of his day, he did not like school at all. The whole bent of his mind and all of his natural inclinations seem to have been toward applied science, particularly pharmacy. Happily, in this case, his parents allowed him to follow a profession in complete accordance with his most heartfelt desires. They wisely determined that they would not put a round stick into a square hole. At the age of fourteen, therefore, he was apprenticed to an apothecary named Bauch, in the far-away town of Gothenburg, some two hundred miles from his father's residence. To reach the place he had to cross the Baltic and make a journey that was very tedious in those days.

From this time on, for nineteen years, Scheele worked for two or three different pharmacists and studied science on the side. He became acquainted with many of the leading chemists of the day and discussed his research problems with them.

In 1775, when he was thirty-three years old, he decided to own a little shop of his own. He heard of a shop which was about to become vacant in a small town, Kaeping, on the

SCHEELE, A DISCOVERER OF STUFF

western side of Lake Maeler, in Sweden. According to the law, he applied for permission to take it over. He passed a successful examination, but found upon taking possession of the place that he had sunk his money in a venture that was almost hopelessly in debt. He rose to the situation and worked very hard to put the business on a sound basis. His business labors, however, did not prevent him from continuing with his scientific studies, but they took so much of his effort and time that he could devote only a small amount of time to research.

A few years later the Royal Swedish Academy, recognizing his unusual value to the world at large, gave him a grant of money which was sufficient to insure him a comfortable living and much leisure. Scheele continued to maintain his apothecary shop, however, spending five-sixths of his pension on financing his experimental work and only one-sixth upon his living expenses.

Scheele called the new yellow gas which he discovered dephlogisticated marine air. This name was in line with the phlogiston theory in vogue at the time. Sir Humphry Davy, an English scientist born four years after chlorine was discovered, was the first person to establish the fact that chlorine was an element and not a compound. Following the establishment of this truth, Davy named the element in 1810. The name which he chose was quite appropriate—*chlorine,* from the Greek word for "greenish-yellow."

BLEACHING WITH CHLORINE

The first industrial use to which chlorine was put was that of bleaching. In 1784 the great French chemist, Claude Louis Berthollet, made the first experiments on bleaching with chlorine, and soon afterwards a firm of linen manufacturers in Aberdeen, and simultaneously one in Glasgow, tried it on a large scale. Five years later this same chemist improved

the chlorine bleaching process by substituting a solution of potassium hypochlorite for the chlorine water which he used at first. He made the potassium hypochlorite by passing chlorine gas into a solution of potash (potassium carbonate). He carried on the investigations that led to his invention of this bleaching agent, at a plant on the Quai de Javelle, Paris. This new product consequently came to be known as Eau de Javelle or Javelle water.

A cheaper method of making Javelle water was found later; this consisted of the passing of chlorine into sodium carbonate instead of into potassium carbonate. Still later it was made by mixing solutions of chlorinated lime and sodium carbonate, and filtering off the insoluble calcium carbonate. The filtrate consisted of a solution of sodium hypochlorite.

This latter method was not possible when Berthollet first made his bleaching solution, because chlorinated lime had not yet been invented. Berthollet sold the rights to his Javelle water process to James Watt, the inventor of the steam engine. Watt, in turn, sold his rights to Charles Tennant, a Scottish industrial chemist. It was Tennant who invented chlorinated lime or bleaching powder. Tennant was engaged in the bleaching industry at Darnley, Scotland.

Since the invention of bleaching powder, this compound and liquid chlorine have competed with each other in the industries. Chlorine has many advantages over the lime-chlorine compound, but the cheap price of the latter has recommended it very strongly.

During the past two or three years the price of bleaching powder has advanced. The result has been that the amount used has fallen off, and the amount of chlorine consumed has increased in the same proportion. The paper and textile industries are the heaviest consumers of chlorine and of chlorinated lime or bleaching powder. These two industries take 87 per cent of the total amount of chlorine manufactured.

CHLORINE AND WARFARE

Chlorine and its compounds played conspicuous parts in the recent war, both as agents of destruction and reconstruction. Most of the poison gases introduced during the war contained the element chlorine or one of its compounds. The Carrel-Dakin Solution, used for quite a different purpose—that of disinfecting deep wounds—is also a compound of this extraordinary element.

Rev. Owen S. Watkins, an army chaplain, tells about the first gas battle of the late war which took place during the second battle of Ypres in the spring of 1917. The following description by Dr. Watkins appeared in the *Methodist Recorder* of London at the time of the battle:

> . . . we saw that which almost caused our hearts to stop beating —figures running wildly and in confusion over the fields.
>
> "The French have broken!" we exclaimed. We hardly believed our words. It seemed so impossible, so inconceivable. For a while we almost thought that the whole French army was in retreat. Gun limbers passed at the gallop, fugitive Zouaves and Turcos clinging to them. In a few minutes the road in front of the asylum was choked with fugitives—soldiers and panic-stricken peasantry from the farms and villages round. The story they told we could not believe; we put it down to their terror-stricken imaginings—a greenish-gray cloud had swept down upon them, turning yellow as it traveled over the country, blasting everything it touched, shriveling up the vegetation. No human courage could face such a peril.
>
> "We can fight, but the good God would not have us stay and be poisoned like rats in the sewer!"
>
> Then there staggered into our midst French soldiers, blinded, coughing, chests heaving, faces an ugly purple color—lips speechless with agony, and behind them in the gas-choked trenches, we learned they had left hundreds of dead and dying comrades. The impossible was only too true.

After the first gas attack at Ypres, it was found that chlorine (the gas first used by the Germans) could be absorbed by pads

soaked with soda and photographer's hypo (sodium carbonate and sodium thiosulfate). These were the only means of protection that were to be had until three million gas masks arrived from England a few days after the opening of the attack.

Although the element chlorine was the first gas used during the war, other gases were soon introduced. Tear gas, mustard gas, and a number of the other well-known war gases consist of compounds of chlorine, some of them more deadly even than chlorine itself. An unknown author has penned the lines quoted below on the subject of chlorine-containing war gases:

Chlorine, heavy and stifling,
Is in poisonous traits only trifling,
As compared with its many offspring,
Which choke and torture and sting.
There's Diphenyl Chlor Arsine,
A tear gas that's poison and mean.
It brings hardened soldiers to tears,
And is worse than the worst of their fears.
Chlor Picrin and Chlor Acetone
Cause people with anguish to moan;
Phosgene (Carbonyl Dichloride)
Is the Death Angel's chief joy and pride.
Trichlor Methyl Chlor Formate
Will seal any poor victim's fate.
Dichlor Di Ethyl Sulfide
Makes men itch till they wish they had died.
And this is a very small number
Of the gases that cause folks to slumber.
As we go down the list they get worse
Like the terrible lines of this verse.

THE CARREL-DAKIN SOLUTION

It seems that no material has ever been discovered that has been put to so many diverse uses as chlorine. If one breathes very much of it, he gets an exceedingly bad cold; but if he inhales only a small fraction of 1 per cent of the gas,

some physicians find that it cures a cold. In times of peace it is used to sterilize water, and to bleach linen, cotton, rayon, and paper. In times of war it is used to exterminate us and to preserve us.

The latter use—that of preserving us—is really one of the great blessings that was born amidst the horrors of the last war.

In wars of olden times, more deaths occurred as a result of infections in wounds than from any other cause. Even if death did not follow a wound, amputations were almost sure to be necessary. In the late war, this state of affairs was radically changed through the ingenuity and labor of two scientists, Dr. Alexis Carrel and Dr. Henry D. Dakin.

Dr. Carrel is a French surgeon who at the opening of the war was engaged in research work at the Rockefeller Institute in New York. His principal contributions to science previous to this time had been his famous work on the transplanting of tissues (legs, eyes, fingers, and other parts of the anatomy) from one animal to another. At the opening of the war, he went to Paris and enlisted in the service. Backed by Rockefeller funds, he established a hospital at Neuilly and commenced work.

Dr. Dakin, an English chemist, was also residing in New York at the opening of the war. He, too, went immediately to the scene of action and entered the chemical corps, ready to tackle any problem in chemistry that should be assigned to him.

One of the first problems that came up for consideration in the treatment of soldiers was that of preventing infection. The practice of airing wounds which was then in vogue did not seem to be conducive of ideal results, but no better method had yet presented itself.

At this point, Dr. Carrel thought of the plan of constantly washing out every nook and cranny of a wound by irrigating it with a suitable antiseptic. Two things were lacking. First, he had no mechanical device suitable for the operation, and second, he had no common antiseptic that would be satisfactory.

THE CARREL-DAKIN METHOD OF TREATING WOUNDS

He undertook the task of devising some sort of apparatus for the purpose, and he gave to Dakin the problem of finding the proper antiseptic. The device which Carrel perfected consisted chiefly of perforated rubber tubes, by means of which every part of a wound could be flooded. The solution which Dakin discovered as appropriate consisted of a neutral one-half per cent solution of sodium hypochlorite. The treatment consisted of flooding the wound every two hours. An extremely

valuable characteristic of the hypochlorite solution, in addition to its remarkable antiseptic powers, is the fact that it dissolves and removes dead tissues.

Hypochlorite of sodium has no curative properties in itself; but, by killing the bacteria present in a wound it leaves Nature free to heal the mangled tissues.

CHLORINE'S COUSINS

Chlorine has three close relatives which are very interesting. In fact, these four elements are so closely related that they are grouped together in science books as the Halogen Family. The names of the members of this family are quite euphonious. In fact, if it were not for the disagreeable properties of some of these substances, they might serve as the inspiration for some fond mother who is searching for appropriate names for quadruplets. They are fluorine, chlorine, bromine, and iodine.

FLUORINE, THE JOINER

Fluorine, a pale yellow gas even more active chemically than chlorine, is the greatest joiner among the chemical elements. If it were a person instead of an inanimate substance, it would belong to every fraternal order from the Rotarians to the Yellow Dogs. It is so chummy in its nature that it combines with glass and porcelain and nearly all of the metals. Because of this fact it was not until 1886 that any one succeeded in isolating it, even though its existence in compounds has been known for a century and a half. In that year, Professor Henri Moissan, a brilliant French chemist, prepared the gas by passing the electric current through one of its compounds in a specially constructed platinum apparatus.

Fluorine is prepared only infrequently at the present time, because it has no uses at all. Hydrogen fluoride, its chief compound, can be prepared quite easily and has a long list of

uses. These range from the removal of rust spots from clothing in commercial laundries and dry cleaning plants to the etching of laboratory and table glassware. For the former purpose it is sold on the market under the trade name Erusticator.

Fluorine exists in minute quantities in the tissues of both plants and animals. Skin, the enamel of the teeth, bones, brain, blood, and milk show traces of this element; and it is believed to be present in practically every tissue in plants and animals, even if the amounts are so slight that it cannot be detected by the common methods of chemical analysis. Recent studies of a biochemical character show that a shortage of fluorine in the diet of animals leads to general physical disorders, the teeth being particularly affected.

BROMINE THE ODORIFEROUS

The third member of the Halogen Family is a heavy brown liquid named bromine. This element was accidentally prepared from sea salt in 1826 by Antoine Jérôme Balard, a young French chemist. The discoverer of this substance very aptly named it *bromine,* which means "the element with the stink."

The chief use of bromine at the present time is in the preparation of ethylene bromide, a compound added to ethyl gasoline to prevent the lead in the gasoline from alloying with the ignition points of spark plugs and injuring them. If all the gasoline used in the United States each year (approximately twelve billion gallons) should be treated with tetraethyl lead and ethylene bromide, about ninety million pounds of bromine would be required.

Another recent use of bromine is in the preparation of complicated organic compounds which serve as tear gases in gaseous warfare. Small amounts of the element are used in the manufacture of dyestuffs. Some of the bromides—salts

of bromine with various metals—are of commercial importance. Silver bromide is used as the sensitive agent on photographic plates and papers. Potassium and sodium bromide are used as sedatives (nerve soothers) in medicine.

Formerly the raw material for the preparation of bromine was derived from the mother-liquors of salt springs and from seawater, especially that of the Dead Sea. Although rich in bromine, this sea was so remote from centers of manufacture that new sources were sought. The second important source to be discovered was in the Strassfurt, Germany, salt deposits. The production of bromine from the Strassfurt salts as a by-product of the potash industry dates from 1865, when A. Frank introduced this branch of industry in order better to compete with potash from kelp and from mineral springs.

More recently, bromine has been produced in the United States. More than two million pounds annually are produced here chiefly from liquors remaining after common salt has been crystallized out of them. The remaining liquor, known as "bittern," is electrolyzed, bromine being set free at the positive pole or anode. The Saginaw Valley, Michigan, furnishes most of the bromine produced in the United States at the present time.

THE GOOD SHIP "ETHYL"

Every 1,700 gallons of seawater contain one pound of bromine, not free, of course, but combined as bromides. The area of the oceans of the globe is about 140,000,000 square miles as compared with less than half as much land. The average depth of the oceans is 3 miles. If suitable methods are devised for extracting the various salts found in seawater, therefore, truly an inexhaustible supply of certain chemical compounds will be available.

In 1924 the Ethyl Gasoline Corporation, in coöperation with the General Motors Research Laboratory, investigated methods

for the recovery of bromine in amounts as dilute as that found in seawater. The purpose of the research was to find out new sources of bromine in case the present supply should become inadequate to meet the demands made upon it. A satisfactory process was devised which worked well on experimental trials. Thereupon the Ethyl Gasoline Corporation and the E. I. du Pont de Nemours Company equipped a ship for trying out the experiment on a wholesale basis.

The ship, named *Ethyl,* was fitted out as a veritable industrial chemical plant, and was sent to sea to be tried out. The trials were successful, and the experiment showed that 100,000 pounds of bromine could be extracted from seawater in a month by the method used. At this rate, 392 years would be required to deplete the bromine supply in 1 cubic mile of seawater.

IODINE

The fourth member of the Halogen Family of elements was also discovered by a Frenchman, Bernard Courtois, who in 1811 accidentally prepared this substance from seaweed ashes. Sir Humphry Davy, the scientist who named fluorine and chlorine, also named this element. He called it *iodine* after a Greek word for "violet." The name referred to the violet color of the vapors emitted when this substance is heated. Iodine at ordinary temperatures is in the form of black, iridescent crystals.

About seventy-five years ago the theory was advanced that thyroid disorders, such as goiter, were caused by a lack of iodine in foods and drinking water. Studies were made at that time which seemed to show that, in geographic regions in which the water and the foods eaten by the people were deficient in iodine content, goiter was generally common. In regions in which iodine was more plentiful in water and foods, on the other hand, this disorder was practically unknown.

From that time on, hundreds of investigations have been

carried on to determine the cause of and the possible cure for goiter and other disorders of a similar nature. Conspicuous among the investigators in this field is Dr. E. C. Kendall of the Mayo Brothers Laboratory at Rochester, Minnesota.

The various pieces of work on goiter resulted in the discovery of the fact that thyroxin, an organic iodine-containing compound, is the active principle of the thyroid gland. Hand in hand with this came the discovery that most of the disorders of the thyroid gland can be cured by daily administrations of thyroxin. Further, it was shown in many cases that iodine compounds other than thyroxin were effective in goiter treatment.

The following summary, given by Dr. Robert Oelesen of the United States Public Health Service in a pamphlet issued by the United States Government, covers briefly the subject of administering iodine in the treatment and prevention of goiter:

It may be stated that while numerous methods of supplying iodine for the prevention of endemic goiter have been suggested, the most favored one at the present time is the administration of a chocolate tablet containing ten milligrams of iodine in the form of an organic acid. One or two of these tablets, according to the age and requirements, should be given each week during the school year both to boys and girls between the ages of 11 and 16. Owing to the presence of thyroid enlargements in children less than 11 years of age, prophylaxis should profitably begin earlier than has ordinarily been recommended. The preventative should be used both in children in whom there is no evidence of thyroid enlargement and in those having such enlargement. In the latter instance, however, the exercise of nominal medical supervision is desirable. . . .

While individual oral administration of iodine is the method generally employed, the use of iodized table salts holds forth considerable promise as an efficient means of preventing goiter in a wholesale manner. However, the difficulties of gauging accurately the dosage and of excluding from treatment the hypersusceptible are manifest handicaps to this uncontrolled application.

The wholesale iodization of a municipal water supply may be cited as an ingenious method in need of further appraisal before a definite verdict as to its efficiency can be given.

According to the best information available, there is little if any danger in iodine prophylaxis when it is carried out intelligently. Moreover, the rationale of the procedure is sufficiently sound and the results are sufficiently marked to make its extensive application both justifiable and advisable.

Iodides play an important part in the physiological processes of animals as well as of human beings. Among the foods used by livestock, the more important sources of iodine are the hay, silage, and forage crops. It is probable that the total iodine requirements of animals may be gleaned from foods that contain so little of this element that its presence would escape detection in ordinary methods of laboratory analysis.

Following the discovery of the importance of iodine to human beings, plans were made in various places for iodizing not only foods and water, but air as well. Physicians do not believe, however, that the iodizing of air has any beneficial effect.

TINCTURE OF IODINE MEETS A RIVAL

Tincture of iodine, a solution of iodine in alcohol, an antiseptic found until recently in almost every household medicine cabinet, has met a rival in mercurochrome. Mercurochrome is a complex mercury-containing compound which has proven to be more effective than iodine, and much less irritating.

Man is thus continually creating new stuff to replace old stuff that is less effective for the purpose intended.

Chemists, however, did not permit iodine to be relegated to the background as an antiseptic. Stimulated by the competition provided by mercurochrome, they produced the so-called colloidal iodine, which is many times more effective than the old-fashioned tincture. Colloidal iodine consists of particles of such minute size that the element can readily be made into an emulsion with water, a process which was not possible with crystalline iodine. Unlike the former alcoholic tinctures, the water suspension is non-irritating when applied to fresh

wounds, nor does it produce blisters. It is also superior in antiseptic qualities.

THE HALOGEN FAMILY ARGUES

A teacher of chemistry recently became sufficiently interested in the characteristics of the members of the chemical family called the Halogens to write the following one-act play:

The characters are to represent the four elements, Fluorine, a pale yellow gas, most active substance imaginable; Chlorine, a greenish-yellow gas, not quite so active chemically as fluorine; Bromine, an amber-colored liquid still less vivacious chemically than chlorine; and Iodine, a black, crystalline solid, fairly sluggish chemically.

The curtain rises on a bare room in the home of the four Halogen sisters. A heated argument is in progress.

FLUORINE.—I tell you that the rest of you are as nothing in comparison with your dashing blonde sister. As far as importance is concerned—

CHLORINE.—Aw, leave off the comedy, Flo. You know you never did a single useful thing in the world by yourself. You always have to have somebody's help—

FLUORINE.—You're wrong there, old carrot-top. It's the other fellow needs my help. Look what sort of a combination hydrogen and I make. Cleverest little partnership you ever heard of. We etch all the neat little grape vines, and conventional forget-me-nots, and I don't know what all on the ladies' table glassware. Hydrogen by himself could never scratch a dent in the tiniest surface of a piece of glass.

CHLORINE.—Neither could you by yourself.

FLUORINE.—Wrong again, you pungent tempered one. As a matter of fact, I'm just a little bit too active for a job of that sort. If I were left unrestrained, I would etch the glass all to pieces, perhaps, and would carve up everything else in sight. Hydrogen is needed to temper my activities.

BROMINE (*rising from a sofa, and approaching the other two sisters with slow, graceful strides*).—I can't see much to glass-etching. Wouldn't the table glasses serve just as well without the dear little designs you speak of?

FLUORINE.—You have nó sense of the artistic, my dear brunette

sister. Besides, if you must see some useful side of etching, look at the neat division marks we make on laboratory graduates and glass equipment of this sort. What would all the chemistry students do without these nice little cubic centimeter and cubic millimeter marks on their laboratory apparatus?

IODINE (*reclining on a sofa*).—A lot they care about those marks you speak of. They'd rather not have to bother with measuring things out accurately.

CHLORINE.—Surest thing. Chemistry students are all the bunk, with their silly laboratory aprons. I surely give them a run for their money the day they start delving into my pedigree. There's many a young budding scientist that I've driven to the outside air, when he came poking around trying to find out about my personal and private habits.

IODINE.—That's about all you are good for, to drive folks to cover. Remember the war.

CHLORINE.—To cover is right, you black-headed, lazy relative. To cover up their faces with gas masks.

FLUORINE.—You must have gotten quite a kick out of the war. I would have enjoyed it if they had chosen to employ me.

IODINE.—I can't see what sort of fun you could get out of making people suffer that way.

CHLORINE.—Well, I can never explain it. You see, I am a bundle of rank inconsistencies. I kill people, and save them from death also.

BROMINE.—Whom did you ever save from death, either sudden or lingering?

CHLORINE.—Pray, get in college. I sterilize all the water of towns and cities, and keep the death angel from getting an entire army of typhoid casualties. Then too, I am the active agent of the firm of Sodium, Oxygen, and Chlorine, commonly known as Dakin's Solution. This combination has practically eliminated gangrene and similar maladies from hospitals, where deep wounds are treated. Then, I am also responsible for the successful treatment of the common cold.

IODINE (*languidly*).—I thought that it was still a matter of controversy in medical circles as to whether or not colds responded satisfactorily to your treatment.

CHLORINE.—Oh well, what's the idea of bringing that up?

FLUORINE.—None whatever. But I can't see those minor activities as important when they are compared with the place that

various of my companies hold in the metallurgical fields. Fluorspar, one of my chief combinations, is absolutely necessary in the steel as well as in many other metal refining industries. Aluminum would never have been produced on a commercial scale except for Cryolite, another company in which little yours truly is one of the chief stockholders.

Bromine.—It would have been a tough break if we couldn't have aluminum for airplane and airship parts.

Iodine.—And kettles.

Chlorine.—Oh, kettles. Who cares about such commonplace things? I go in a lot for the æsthetic. Take bleaching, for example. I bleach cottons, linens, and rayons, so that they can be used snowy white, or so that they will take beautifully colored dyes.

Bromine.—Sewage disposal, too! I presume you number this among your artistic undertakings?

Chlorine.—Even that is not to be sneezed at. And I haven't heard you offer anything to this debate except the most destructive comments.

Bromine.—Oh well, as far as that's concerned, I guess I could hold up my head with the rest of the family. I've driven about as many students out of the laboratory as the next one. And as for bad tempers, they surely handle me with care. I travel around in hermetically sealed containers packed in sawdust.

Fluorine.—But we haven't heard anything good about you yet.

Bromine.—Exercise a little tolerance, capricious minx. What about my use with anti-knocks gas? Or the various beautiful dyes that I help to make? Or the photographic plates that I sensitize? Think of all the family albums for which I am responsible.

Iodine.—Yes, you and Silver. Besides, family albums are nothing to shout about. Think how many people they've bored.

Bromine.—Oh well, if you want to be modernistic, there's the cinematograph. Both kinds, the professional and the kind taken at home showing baby cutting his first tooth, and so on.

Iodine.—For the matter of that, I would serve almost as well as you in this photographic capacity.

Bromine.—You're too slow! You let Mercurochrome nab the best thing you ever did. What else are you good for?

Iodine.—You're behind the times again. A new type of "colloidal iodine" antiseptic is competing very successfully with the product you mention. Besides, think of all the goiters I prevent. And besides, you do not know enough about synthetic organic chemistry

to appreciate my rôle in life, if I should tell you. What do you know about dyes, or drugs, or—?

FLUORINE.—Are those rhetorical questions or do they require answers?

IODINE.—I can't be bothered.

FOOD TURNS THE WHEELS OF INDUSTRY

As ships and trains need fuel, and as factories need raw materials, so the body needs food.

CHAPTER V

FOODSTUFF

To stuffe for your good store,
to gnaw, chew, bite, and eat.
—HARINGTON (1596)

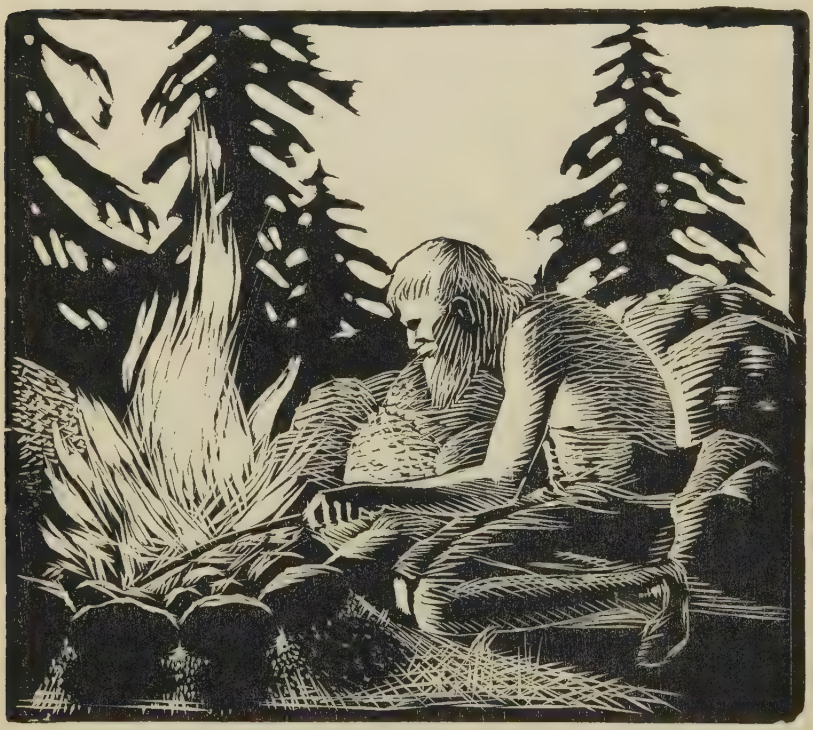
THE search for food has occupied the human race from the beginning of time. We could do without railroads and radios; we could even adapt ourselves to live without clothing and houses; but food we must have.

In his search for food man has ransacked the whole earth. He has hunted through the animal, the vegetable, and the mineral kingdom, and has taken therefrom everything that seemed suitable to him. He has explored the mountain tops and dredged the seas to increase the quantity and to add to the variety of his foods. The search for food still continues, and it becomes keener and keener as the number of people living on the earth increases.

FEASTING AND FASTING

The most ancient tribes of people ate their food raw, because fire was not yet discovered. They ate wild fruit and herbs and whatever else they could find in a world where plants grew wild and where the hand of man had not yet been applied to agriculture. Soon they were forced to add game to their list, since wild and uncared-for plants yielded only scanty and unsatisfying articles of diet. When an especially large supply of herbs and fruits was found, and when some wild game was killed, a feast was held. When the members of a tribe had gorged themselves at a feast of this sort and had eaten the last remnants of the food, they started out again in search of food.

This continuous round of feasting and famine made up the life of primitive man. He ate all that he could when food was at hand, and stored none against a time of need, since no means of preserving foodstuffs had then been discovered.



PRIMITIVE MAN TAKES A STEP UPWARD

By discovering that fire could be used to cook food and thus add to its flavor, our caveman ancestors laid the foundations of the home, agricultural pursuits, and the raising of domestic animals.

THE INTRODUCTION OF COOKING

The discovery of fire led to many improvements in man's eating habits. The manner in which the cooking of food came into practice is the subject of many myths and legends. None of these are known to be true, because no records were being

written at the time when the custom originated. The most reasonable explanation is that during some prehistoric banquet a member of a primitive tribe accidentally dropped his piece of raw meat in the open fire, around which the people were grouped to keep themselves warm. It is quite natural to believe that he would dig around the fire with sticks and try to recover his meat. When he was finally successful in getting the piece out of the fire, he no doubt went on eating it, thinking to get as much enjoyment as possible out of the damaged remnants. The improvement in taste, even though the cooking was not very thorough, would surely have appealed to him and must have led him to encourage other members of the group to experiment with their portions in the same way.

We shall never know, of course, whether or not this bit of conjecture gives the exact details of the method by which the very first food was ever cooked. No matter how it came about, it is a fact that man found at an early time that cooked food was better than raw, and that in addition it would not spoil so readily.

THE HOME

The discovery of fire complicated the problems of prehistoric men. Previous to this they had been free to move from place to place, killing and eating whatever game they could find, and plucking whatever the vegetable kingdom had to offer in the way of wild fruits. For shelter they crouched under overhanging rocks or stayed in caves or other naturally prepared dwellings. For weapons they used wooden clubs or stones or whatever else Nature had to offer. The discovery of fire made it possible for them to cook their food and fashion many articles of everyday use; but it also made it difficult for them to wander from place to place because the fire was tedious to start.

THE BEGINNINGS OF AGRICULTURE

The discovery of fire had another very important effect on the food situation of the human race, resulting from the fact

that women were left at home to keep the fire from going out. While keeping up the fire and tending to her other simple duties around the rude home, the primitive housewife frequently found time to go short distances in search of fruits and herbs, so that these could be added to the meal when the man should return with his game. When she found a plant that yielded more fruit than was necessary for the immediate present, nothing could have been more natural than that she should build a rude fence of sticks around it to keep hunters and wild animals from trampling it down. She likewise pulled up plants growing at some distance away and stuck their roots in the ground near her own fireside. She guarded these with care, pulling up other useless plants which threatened to crowd them out. When she found that her herbs flourished best when the soil was loose around them, she worked the soil with a stick. Such were the rude beginnings of agriculture.

While the woman was taking the first steps toward the cultivation of plants, it was the man who first thought of the plan of bringing home live animals and keeping them alive until they should be needed as food. It is thought that this idea originated when one of a group of primitive huntsmen, returning with game from a successful hunting trip, threw a stone at a passing animal and succeeded in wounding but not killing it. Since the group probably had already secured all the game they could eat before it would spoil, they decided to carry home the wounded animal alive and feed it on herbs until the meat supply should run low.

Thus the idea of cultivating plants and of rearing animals came about. It resulted in making man's food supply more reliable from day to day, since he could raise as many plants and animals as he needed, and could have them on hand when he required them.

To-day, methods of preserving and transporting food have been perfected to such a degree that a bill of fare in January is no different from that in June, and there is little difference

in the diet of those of the North and those of the South, or of those living on the seacoast and those inland. It is, therefore, not at all difficult for us, if we have the money to pay for it, to secure at any time what we like to call a good, square meal.

ADDING CORNERS TO THE SQUARE MEAL

The term *square meal* sounds quite filling, but as a matter of fact it is not a square meal that we require, but a six-sided one. If any of the six sides are neglected, the body is not properly nourished, and serious trouble will result.

The first and most important of these sides is water. Water actually makes up three-quarters of the entire weight of the human body. It is present in all the tissues. It is even found in the enamel of the teeth to the extent of 2 per cent. Because it can hold other food substances in solution, it serves to carry digested food through the walls of the stomach and intestines into the blood, and in this way to all parts of the body. Human beings can live longer without solid food than they can without water.

MATERIALS NEEDED FOR BODY MAINTENANCE

The body also requires a certain amount of protein each day. Protein is a word which the chemist applies to a group of compounds found in such animal foods as lean meat, eggs, and milk, and in such plant foods as beans, peas, and grains. Proteins contain a number of elements, chiefly carbon, hydrogen, oxygen, and nitrogen. The first three of these are found in other kinds of foods, but nitrogen is not found in a form available for use by the body in any compounds except proteins. Nitrogen is needed in building up every single tissue of the body—muscle, bone, tendon, brain, and nerve. While we are growing we need protein foods, of course, because our bodies are increasing in size. Even after we have attained our

full growth we still need protein-containing foods to repair the parts of our bodies that are constantly wearing out. With every wink of the eye, in eating and digesting our foods, and even in breathing, we are tearing down some of the tissues of our bodies. These can no more be rebuilt without protein-containing foods than a leaky pipe can be mended without solder. Protein foods are so necessary to the body that it is perfectly possible for us to eat a bulky meal and still be underfed if the meal contains no milk, meat, eggs, or other protein-containing food.

Bones are composed of two main types of substances—proteins and mineral substances. A well-known experiment performed in almost every elementary physiology class consists of placing acid on bones until all of the mineral compounds are dissolved out, and then heating other bones on an iron dish until all of the protein matter has gone up in smoke. In the former experiment, the bone becomes sufficiently limber to enable it to be tied in a knot. In the latter, nothing but a white ash remains.

If human beings do not get the proper kinds and amounts of mineral substances for bone growth, or if they have some physiological disorder which makes it impossible for them to utilize what they get, they suffer from rickets and other bone troubles. Bowed legs are but one of the many results of improper mineral nutrition in growing children.

Calcium and phosphorus are the two chief mineral elements needed for bone growth. Magnesium also is important, though in lesser quantities. These materials are furnished by such well-known foods as milk, meat, eggs, and some of the common vegetables.

The body needs something in addition to the materials for building and repairing itself. It requires fuel. It can no more be made to move around and perform its necessary activities without energy-giving foods than an engine can run without coal. The chief fuels used by the body come under a class of compounds called carbohydrates. Two forms of carbohydrates

which man uses as food are the starches and sugars. Bread, cereals, potatoes, and macaroni are important energy-giving foods. In addition, we have milk, which contains a kind of sugar called lactose; carrots and peas, which contain starch; and fruits, which contain varying amounts of sugar.

All carbohydrates contain the elements hydrogen, carbon, and oxygen. No matter what kind of a carbohydrate we eat, it is changed by the digestive juices of the mouth and intestines into simple sugars, chiefly glucose. The simple sugars formed during digestion dissolve in the water of the intestines and pass through the walls of these organs into the blood. Some of them are stored in the various muscles of the body in the form of an insoluble carbohydrate, ready to serve as fuel at the moment it is needed. Any excess of what is needed for immediate use is changed to an insoluble carbohydrate and is stored in the fuel warehouse, the liver, ready to be delivered to the blood in a soluble form when needed.

The chief use of carbohydrates in the body is that of serving as a fuel. The sugar stored up in the muscles of the body unites with the oxygen of the air taken in through the lungs and distributed through the body by the red corpuscles. This union produces heat needed to keep the body warm, as well as energy needed for doing its proper work.

Fats serve as insulators and as a reserve fuel. Such foods as butter, cream, bacon, and the fatty parts of meat contain the group of food substances called fats. Fats contain exactly the same chemical elements as carbohydrates, but these elements are hooked together differently. These two types of food substances are so similar, however, that they can be changed from one to another in the body. If a person eats a larger amount of candy or any other carbohydrate-containing food than the body can use immediately or store up in the liver, the elements in the carbohydrates may be rearranged and stored up in the body as fats.

Fats serve two purposes in the body. Each muscle, whether

it be a tiny one which helps to pull the eyelids up and down, or a large one as found in the thigh, is padded with a layer of fat. This fat acts as a blanket to keep the body warm. People who are quite thin shiver from the cold much more intensely than those whose muscles are smoothly padded with fat. Some people, however, eat such a large proportion of fat-producing foods and take such a small amount of exercise that they lay on fat in ridiculous amounts, and any one knows that this is a burden to them rather than a benefit.

All excessively fat people have not become so because of overeating and underexercising. Some people seem to become fat in spite of their own efforts to the contrary. This is attributed to a failure of the pituitary glands, located in the brain, to function properly.

Besides serving directly to keep the body warm by supplying a padding around the muscles, fats act also as a reserve fuel supply. If a person takes a great deal of exercise at one time, and the carbohydrates supply of the body runs low, fats are drawn upon as a source of energy. If both the carbohydrates and fats of the body are heavily drawn upon before more food is eaten, the very protein tissues of the body itself are oxidized. This last method of getting fuel, however, is a very costly one indeed.

MATERIALS REGULATING BODY PROCESSES

Common salt, and various calcium, potassium, and other mineral substances, are needed by the body to enable it to carry on each one of its many functions. Muscles relax and contract only if surrounded by solutions of mineral salts of exactly the correct make-up. Nervous impulses, processes of digestion and assimilation, the combining of red blood corpuscles with oxygen, and every other physiological process calls for certain mineral salts in definite amounts. Iron is needed to build up the red corpuscles so important in carrying oxygen to all parts of the body.

VITAMINS

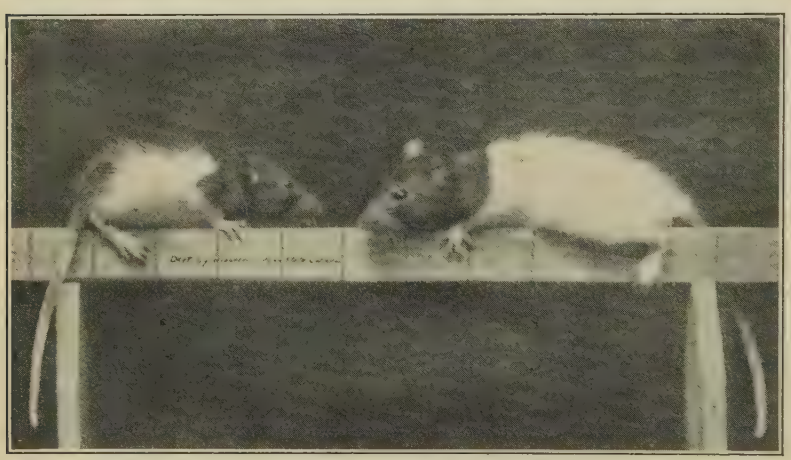
There is still another kind of food substance which has come to be recognized in very recent times as a necessary part of the everyday dietary. Before the need of this type of food constituent was recognized, many cases of suffering and disease were endured by people who ate foods containing an insufficient amount of this necessary factor. Scurvy was one disease that was common during the last century. This disease affected particularly those people who made long ocean voyages on whaling or exploring vessels, their diet being limited to canned and dried foods. The following extract is taken from the diary of Dr. Elisha Kane, a famous American Arctic explorer of the past century:

> December 2, Saturday [1854]—Had to put McGary and Riley under active treatment for scurvy. Gums retracted, ankles swollen, and bad lumbago. Mr. Wilson's case, a still worse one, has been brought under. Morton's is a saddening one: I cannot afford to lose him. He is not only one of my most intelligent men, but he is daring, cool, and in every way trustworthy. His tendon Achilles has been completely perforated, and the surface of the heel bone exposed. An operation in cold, darkness, and privation would probably bring on locked jaw. Brooks grows discouraged; the poor fellow has scurvy in his stump, and his leg is drawn up by the contraction of the flexors at the knee-joint. This is the third case on board—the fourth if I include my own—of contracted tendons.

In Dr. Kane's time it was thought that scurvy was caused by eating too much salt pork. At the present time we know that it results from failing to eat foods containing a certain vitamin or food substance necessary to health. Lemons, tomatoes, and oranges, as well as some other fresh fruits and vegetables, contain the food substance that prevents and cures this disease. Even at the time of Dr. Kane's expedition, it was known that a peculiar kind of Arctic grass called scurvy grass would reduce the suffering from scurvy, and also that

potatoes seemed to have a slightly beneficial effect. The following note is taken from Dr. Kane's diary of December 5, 1854:

McGary is no better, but happily he has no notion of how bad he is. I have to give him a grating of our treasured potatoes. He and Brooks will doubtless finish the two I have got out and then there will be left twelve. They are now three years old, poor old frozen memorials of the dear land they grew in. They are worth more than their weight in gold.



USE OF ANIMALS IN VITAMIN EXPERIMENTS

These white mice enjoyed identical rations, except for the fact that the one at the left was not given one of the necessary vitamins.

It is regrettable that the people of olden times did not know the cause of scurvy, nor the fact that a few spoonfuls of lemon juice a day would ward it off. To-day, scurvy is quite uncommon because people know more about the proper selection of foods than they once did.

Scurvy is not the only disease resulting from a diet that is lacking in certain vitamins. Beri-beri is a common disease in certain parts of Asia where the natives live almost entirely on polished rice. The fault with this diet is not that the polished

rice is bad, but that it does not contain all of the food substances that people need. It is lacking particularly in a vitamin required for satisfactory nourishment of the body. The seed-coats of the rice, which have been removed during the polishing of the grain, contain small amounts of this vitamin. People living on whole rice, and those living on polished rice and some other foods containing the vitamin not present in polished rice, are not afflicted by this disease. The vitamin in the absence of which beri-beri develops is contained in such every-day foods as milk, cereals, bread, carrots, potatoes, and many other fresh vegetables.

Besides scurvy and beri-beri, there are other diseases that are known to result from a lack of one or more vitamins in the diet. One of these, a serious eye trouble, afflicted hundreds of children in the European war zone, because they could not get the right kind of food. Pellagra, a disease known in parts of this country, is likewise caused by the lack of the right kind of foods. Rickets, a disease of young children in which the bones do not develop properly, results from a lack of sunlight, a lack of the proper mineral constituents in the diet, and a lack of a particular vitamin. Scientists have already discovered the presence of a considerable number of distinct kinds of vitamins in foods, and there are undoubtedly many others which they have not yet learned to recognize.

NATURE'S FOOD FACTORY

With the large variety of foods at our disposal, it should not be difficult to plan a well proportioned meal, with water, proteins, carbohydrates, fats, mineral compounds, and vitamins in sufficient quantity to keep one well and strong. Mother Nature is constantly manufacturing foods for our use.

Nature's process of food-building is more important than any chemical process carried out by man in the chemical laboratory. The out-of-doors is Nature's workshop. The ma-

terials she uses are moisture, which is plentiful and cheap; carbon dioxide, which is a waste product exhaled from the lungs of man and animals; and mineral matter found in the soil. Since man is absolutely incapable of taking these crude materials and using them directly as foods, Nature helps him out. Plants are the agents she used to take the raw materials out of the air and soil and to bring about a combination of these substances. Moisture and carbon dioxide unite in the leaves of plants. The energy which brings about this union is light from the sun. The screen that absorbs the chemically active rays of sunlight is leaf-green or chlorophyll. The products formed by the union of these two materials are chiefly carbohydrates, which the plant uses for food.

Plants require not only carbohydrates, but proteins, for building up their tissues. They therefore convert some of the carbohydrates, which they build up, into proteins by combining them with nitrogen and other elements which they obtain from the mineral matter of soil.

Human beings obtain the food substances built up by the plants either by eating the plants directly or by eating animals that have eaten the plants. Thus the elements formerly present in the air and soil, and the energy that comes from the sun, is made available for our use in Nature's own laboratory.

VARIETY IN FOODS

Nature does not skimp as to the variety of kinds of foods that she prepares for human beings. Some people do not realize how many kinds of foods there are in the world, and they eat meal after meal of the very same three or four articles of diet. This not only becomes extremely monotonous, but it also may fail to supply them with all the food materials they should have in order to be healthy.

The various races of men living in different parts of the world are by no means agreed as to which of Nature's foods

are best. We would spurn boiled dog, yet certain tribes of the Philippine Islanders consider this a splendid dish. We count oysters an excellent food, while the Turk, on the other hand, holds them in high disdain. Skunk meat would certainly not appeal to us, yet the people in some parts of the world consider this a rare delicacy. In California the best

VEGETABLES NEED NOT BE MONOTONOUS

This display of the offerings of a roadside market gardener contains some twenty-six different vegetables, ranging from the humble onion and cabbage to the aristocratic chard and Chinese cabbage.

fish is said to be the sculpin, yet in the eastern part of the United States this fish goes begging because it is so ugly in appearance. In the United States the common squid would offend one's sense of propriety in food, yet the Italians, French, and Portuguese consider it a most excellent sea food. We would not think of eating lizards, because we think of them as reptiles. Some people, however, eat lizards and enjoy them. Some South Americans even eat large snakes and consider

their flavor to be similar to that of chicken. We are offended by the idea of snakes, but when we eat turtle soup, we evidently forget that turtles are likewise reptiles.

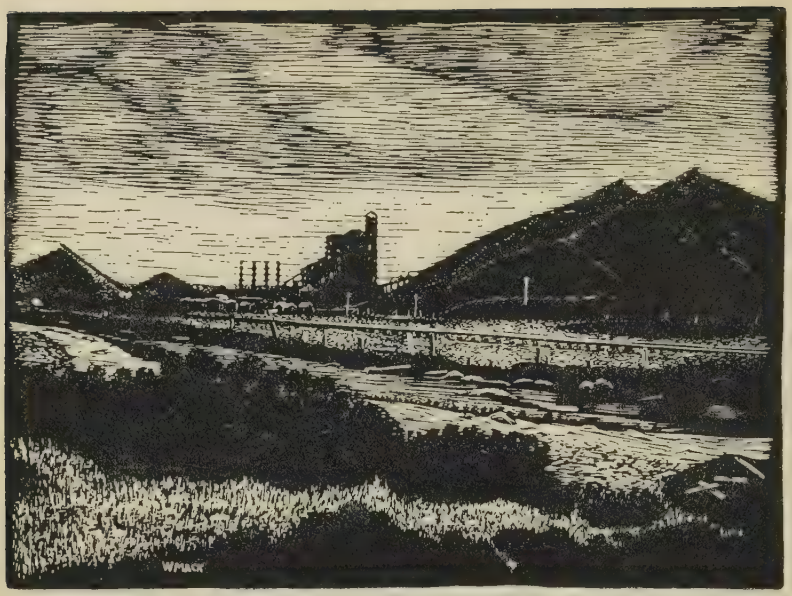
A century ago the English spoke disdainfully of the French as a frog-eating people. To-day there is scarcely a European or an American who would not relish a dish of fried frogs' legs.

Many other foods which various races of people find appetizing would not make the slightest appeal to us. Roasted spiders, for example, are considered a dainty food by the New Caledonians. The Creoles of Bourbon broil and eat cockroaches. The Mexicans have a special fondness for the honey-ants. The Brazilians also eat ants. The Arabs of the desert follow the example of John the Baptist and eat locusts. Those who do not care to catch their own locusts can buy salted ones on the market. The Chinese consider braised canned earthworms a rare treat, and the wealthy members of this race will pay five dollars a pound for shark fins and twenty-five dollars for the choicest edible birds' nests. Bees, caterpillars, grasshoppers, worms, and parrots are but a few of the foods that some races of people enjoy, while others would consider them absolutely unfit to eat.

It should never become necessary, however, for any of us to eat foods which would be offensive to us, yet many really good foods are not eaten because we are either too afraid or too stubborn to try new things. Prejudice has kept people of all ages from trying new kinds of food that they might have liked had they given themselves a chance.

Dr. Samuel Johnson wrote an English dictionary a century and a half ago, in which he defined oats as "a food for men in Scotland and horses in England." If this worthy gentleman were alive to-day, he would surely be startled at our modern array of breakfast foods in which oats are featured quite notably. In the same way, some foods that we are now passing by as useless may be considered extremely satisfactory a hundred years from now.

We hear a great deal about the future possibility of food famines in this country. If people will adapt themselves to a wide variety of foods instead of depending on two or three kinds, there will be little danger of starving if a certain crop fails. The United States Department of Agriculture devotes considerable time to the search for new kinds of plants, which can be grown in this country. One example will show how important this work is. The dasheen is a vegetable which was absolutely unknown in this country until it was introduced by the Department of Agriculture a few years ago. This vegetable is oval in shape, weighing sometimes as much as five pounds. In appearance it is quite different from any other common vegetable. In taste and cooking qualities, however, it is quite similar to the potato. The dasheen will grow in places where potatoes will not, and is not so liable to crop failure as the latter well-known article of food. Dasheens are now being raised on a commercial scale in the southeastern part of the United States, and are being shipped in carload lots to other parts of the country. In a few years a potato crop failure will not seriously handicap us, since such a good substitute stands ready to take its place.



THE SOURCE OF HEAT

To the casual observer, this is simply the entrance to a coal mine. To the person who has been initiated into the secrets of the science of stuff, it is the fountain head not only of heat, but also of a horde of important commodities which bear no resemblance to coal.

CHAPTER VI

HOT STUFF

. . . but as his part is that goeth down to the battle, so shall his part be that tarrieth by the stuff: they shall part alike.

—I Samuel 30:24

THE most ancient human inhabitants of this earth ate their food raw and accepted any kind of hot or cold weather that came their way. Fire was discovered at a very early date, however, and it then became possible to live more comfortably.

The way in which man first came to know about fire and how to use it is a matter only for conjecture, for it happened long before records of any sort began to be kept. Stray sparks

generated while an ancient stone implement was being hewn out may have lighted some nearby combustible material; or perhaps lightning, or the discharge of a volcano, may have started the first fire. There are numbers of ways in which fires may have been ignited accidentally. There is no doubt but that the different prehistoric peoples found out about this phenomenon each in their own way, since there was little or no communication between the various parts of the world.

However it was that fire came to be known, its discovery marks the advent of the domestic fireside, and the beginning of all the industries and all the arts. When homes became established because of the discovery of fire, it became possible for men to accumulate more articles of daily use than when every one wandered from place to place. According to the quotation at the beginning of the chapter, it was considered in ancient times to be quite as important to "tarry by the stuff" as to engage in more heroic and spectacular activities.

FIRE CONSIDERED SACRED

The trouble involved in starting the family fire led to the practice, followed in many ancient villages, of keeping a fire continually burning in some central place for relighting purposes. From this custom, the central village fire came to be regarded as sacred and to be guarded by specially ordained persons as a religious rite.

The Roman worship of Vesta came indirectly from the central village fire custom. Before the altar of Vesta, Roman goddess of fire and the hearth, an ever burning sacred fire was guarded by Vestal Virgins. The Vestal Virgins were selected by the ruler and other high officials from the most attractive young Roman girls from six to ten years of age. These girls were consecrated to their task by elaborate religious ceremonies. The first ten years after their selection they underwent a course of instruction which was to fit them

BEFORE THE AGE OF EXPLOSIVES

Miners in ancient times were obliged to soften the rocks in the veins in which they were working by means of fire. Agricola, in his *De Re Metallica,* describes the method of firing a mine as follows: "For, if a vein held in the rocks can not be hewn out because of the hardness or other difficulty . . . a heap of dried logs is placed against the rock and fired. . . . Even if the vein is a very wide one, as tin veins usually are, miners excavate into the small streaks, and into these hollows they put dry wood and place amongst them at frequent intervals sticks, all sides of which are shaved down fan-shaped, which easily take light, and communicate it to the other bundles of wood."

for their sacred task. The following ten years they actively served at the altar of the goddess. The final ten years of their service they taught the young girls who were being trained. After thirty years they retired to private life.

The honor of being a Vestal Virgin was very great and was much sought after among Roman girls. If a Virgin permitted

the sacred fire to go out while she was on duty, which rarely happened, she was punished severely. In those cases the fire could only be rekindled by the use of sacred instruments and with elaborate ceremony.

FUEL

Starting the fire is now the least of our difficulties, but keeping it going is one of our greatest problems. Whereas the ancients found wood on every hand, and used this lavishly on their fires, we find the problem of securing fuels increasingly complicated.

Because of the rapid demolition of the world's supply of wood, it does not seem probable that wood will ever again take a leading place as a fuel. In rural communities where its use as a fuel would prevent it from being wasted altogether, the United States Government is encouraging its utilization as a matter of economy. As a general fuel, however, its day is done, both because of its high price and its low heating value as compared with coal and other fuels.

COAL

"Coal in truth stands not beside, but entirely above, all other commodities," wrote W. Stanley Jevons in 1865 in his book *The Coal Question*. "It is the material source of the energy of the country—the universal aid—the factor in everything we do. With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times.

"The progress of Science, and the improvements in the Arts, will tend to increase the supremacy of steam and coal."

Coal is formed by a long process of decomposition of vegetable matter. Vegetable matter consists essentially of cellulose, a substance consisting of carbon, hydrogen, and oxygen. The elementary analysis of coal shows that it has a

much lower percentage of hydrogen and oxygen and a much higher proportion of carbon than cellulose. During the long process of formation, therefore, it must have gradually been losing hydrogen and oxygen in the form of water.

Of course coal always contains mineral substances in smaller or larger quantities because of its association with them underground. Larger pieces of shale and rock which may be

IT OUTRIVALS ALADDIN'S LAMP

"To many, the word *coal* conjures up a mental picture of piles of black lumps, or of soot, smoke, and ashes; but to one who really knows and appreciates coal, it outrivals the tarnished lamp which Aladdin rubbed with such amazing consequences." (W. T. Thom, Jr., *Petroleum and Coal, the Keys to the Future.*)

mixed with the coal during mining are removed when the coal is prepared for market. Some mineral constituents are an intimate part of the coal lump. The smaller the amount of these, however, the better the burning quality of the coal.

According to an exhaustive report on the world's coal resources, issued in 1913 by the International Geological Congress, the possible reserves of coal of all kinds, including anthracite, bituminous, and lignite, available within 6,000 feet of the surface of the earth were found to be about seven and

three-fourths trillion tons. Of the estimated reserves, 6.75 per cent is anthracite, 52.75 per cent is bituminous, 40.50 per cent is lignite.

The geographic location of the estimated reserves is as follows:

	Per Cent
America	69 [1]
Asia	17.3
Europe	10.6
Oceania	2.4
Africa	.8

COAL, A RECENT FUEL

"Coal is comparatively a newcomer into civilization," said Lord Melchett of England, in a paper read before one of the great international coal conferences held during recent times at The Carnegie Institute of Technology at Pittsburgh.

We have certain evidence [he continues] of the existence of a highly developed civilization six thousand years before the beginning of the Christian era, evidence gathered, I may say in passing, by an Anglo-American expedition, and it is certain that civilization of a kind is far older than six thousand years. In comparison with this length of time coal came into use but the day before yesterday. In England, for example, we read interesting facts concerning its use in the reign of Edward the First.

The product so noted was outcrop coal which was often washed up on the seashore and which was therefore usually known as sea coal. Coal at first was received with very great disfavor. On a Patent Roll under date June 28th, 1307, the following was recorded relating to the various prelates and magnates of the realm who had been disturbed by the smoke of coal in operations where charcoal had formerly been used by smelters "whereby an intolerable stench diffuses itself in the neighborhood and infects the air, in consequence whereof the King commands the Mayor and Sheriffs of London and

[1] Almost wholly in North America. The United States is estimated to have about 3,140,000,000,000 tons.

the Sheriffs of Middlesex and Surrey to make a proclamation that all persons wishing to exercise that mystery should cease to use coal." If the ordinance were not observed the offenders were to be punished by grievous fines! Fifty years before this Queen Eleanor had been forced to leave Nottingham Castle on account of the smoke of sea coal.

SCENE OF THE DISCOVERY OF ANTHRACITE COAL

The town of Nesquehoning, Carbon County, Pennsylvania, near Mauch Chunk Mountain, where Philip Ginter, a backwoodsman, in 1791 kicked a piece of "black rock" out of his path. The "black rock" was later discovered to be anthracite coal.

For centuries the wealthier classes in London regarded coal as inferior to both charcoal and wood and objectionable in its results. While in this country [the United States] there may be few who would desire to burn coal in the open grate (a relic no doubt of its early history and for the same reasons) in Britain the majority of the population in spite of continuous appeals on behalf of fuel economy still prefer to see the flickering glow of the flame and the spiral ascent of the smoke.

Soft coal, which is much more plentiful than anthracite, has been longer in use than the latter. In fact, when anthracite was first discovered in Eastern Pennsylvania (where most of it is still produced) the first attempts to use it were futile. The reasons for the failure were twofold. First, the coal was exceedingly difficult to kindle; and second, having been kindled, it reached such a high temperature that it endangered the boilers, designed as they were for burning wood, the old method of heating.

Anthracite coal was discovered in eastern Pennsylvania by Philip Ginter, a hunter by occupation, in the year 1791. In order to make sure that he had found coal, Ginter took the piece of black material that he had found near Mauch Chunk Mountain, Carbon County, to Jacob Weiss living at Fort Allen (now Weisport). Weiss in turn took the piece to Philadelphia for investigation.

Ginter was paid for his find, and the Lehigh Coal Mine Company (the present Lehigh Coal and Navigation Company) was founded the following year. Robert Morris, the celebrated financier, was one of the founders of this company. It required a little over twenty years for the industry to get anything like a start. This was because of the hazards of river and canal navigation, and the difficulties involved in burning anthracite. One of the early shipments of anthracite to Philadelphia was without purchasers until the city authorities bought it for use at their water works. When the engineer could not make it burn, it was then used for graveling the walks around the works.

In 1827 Jonah and George Thompson, of Philadelphia, were among the first to use Pennsylvania anthracite coal successfully. These brothers owned iron works on the Schuylkill River, 26 miles from Philadelphia. They had constructed a new hundred horsepower engine in 1824 and 1825, but were unsuccessful in using anything but wood as a fuel for over two years. They finally modified the size of the boiler, the arrange-

ment of the drafts and flues, and the position of the doors until the burning of anthracite was possible.

In commenting upon the success of the Thompsons in their new fuel venture, an issue of a West Chester, Pennsylvania, paper of a little over one hundred years ago said:

> We understand that the Messrs. Thompsons, at the Phoenix Nail Works, on French Creek, have fully succeeded in constructing a furnace for a steam engine calculated for the use of anthracite coal, and in discovering a mode by which this fuel may be most advantageously applied to that important purpose. We would heartily congratulate the eastern section of the State upon this valuable discovery. Nothing within our knowledge has occurred of recent date which can have a more auspicious influence upon our manufacturing interests . . . no one will doubt who will take the trouble to reflect upon the consequences which have resulted to other countries from the possession of a cheap and abundant fuel for the use of steam engines and other similar purposes. This may emphatically be said to be one of the mainsprings of England's greatness. It is this, too, which has largely contributed to make Pittsburgh, which, within the recollection of many a one now living, was but a military station in the western wilderness, one of the first manufacturing towns in our widespread territory.

BUYING COAL ON SPECIFICATION

Most people think of coal as a hard, black substance which costs more than it should and which smokes as a matter of course. Some day the householder is going to buy coal with as much intelligence as the man who buys in large quantities, and therefore must use some judgment in his selection.

Two lumps of coal may have quite a similar appearance and still be entirely unlike in the feature that counts most—its burning quality. In buying coal, therefore, the following points are important:

How much heat will it give?
How smoky will it be?
How much ash will it leave?

Will the ashes be clean or dirty, clinker-like or fine?

When a purchasing agent of the United States Government or of a large manufacturing concern buys coal, he knows in advance the answers to all of these questions. He buys coal "on specification," the specifications stating definitely just what is expected as to heating value and other characteristics. When the coal is delivered, representative samples are taken; and when the samples are crushed, mixed, and reduced to a suitable size, the coal is tested in a laboratory to see whether or not it meets the specifications. The heating value is determined by means of a calorimeter, a special steel bomb in which a weighed sample is ignited in the presence of compressed oxygen, and the heat given off determined. Other tests are made in an exact quantitative way.

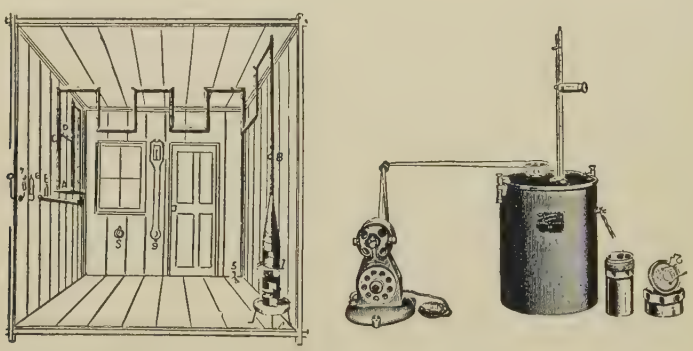
There are many people who hope to see the day when some feasible plan will be devised by which the ordinary owner or renter of a small house can buy coal, or whatever fuel comes along to take its place, on specification, so that he will get full value for his money.

CALORIMETERS

A calorimeter is, as the name implies, an instrument for measuring heat. A fuel calorimeter is a steel container in which a weighed amount of the fuel is burned in the presence of oxygen to insure rapid and complete combustion. The heat generated is transferred to a weighed amount of water in which the steel container rests. The rise in temperature of the water can be read from an accurate thermometer.

Calorimeters for measuring the amount of energy obtainable by animals, or even human beings, as a result of eating certain foods are found in a number of nutrition laboratories of the country. The first human calorimeter built in this country was designed by the late W. O. Atwater of Wesleyan University, Middletown, Connecticut. The first animal calorim-

eter was built at the Pennsylvania State College by the late Professor Henry Prentiss Armsby. In a calorimeter of the type built by these men, the subject studied is placed in a specially built, well insulated room in which the quantity of oxygen taken out of a stream of constantly circulating air, the amount of heat generated, the food eaten, etc., are accurately recorded. Any student interested in reading about calorimeters can find many references on the subject.



THE FIRST FUEL CALORIMETER AND A MODERN MODEL

In 1826 Marcus Bull, a scientist, presented a paper entitled "What Fuel?" to the American Philosophical Society. The work upon which Mr. Bull's paper was based marks the first experimental work recorded on the comparative heating values of fuels. For his experiments he built a small insulated room in which he burned in a stove a given weight of fuel in such a way as to maintain a fixed temperature for a measured length of time. His results gave comparative values for the fuels with which he experimented.

AMOUNT OF COAL MINED

About 600,000,000 tons of coal are mined a year in the United States. Charles P. Steinmetz calculated that if this

quantity of substance were used as a building material, it would make a wall as high as the Chinese wall, entirely around the United States. He further estimated that if we could convert all the energy of a single year's supply of coal into mechanical energy, we would obtain sufficient power to lift this wall to a height of 200 miles.

Geologists tell us we have used 25,000,000,000 tons of the 3,140,000,000,000 tons available in the United States.

The annual fuel bill for domestic purposes alone in the United States is well above one billion dollars.

"Old King Coal is a merry old soul," said the late E. E. Slosson, "and, during his reign of 250 years, the countries that have come under his sway have enjoyed unprecedented prosperity, increased in population, and carried the pursuit of pleasure to a higher point than ever before in the history of the world. 'Long live the King!' is the cry of all of us who live in this Golden Age of fossil fuel, but the more thoughtful of us, remembering that such loyal prayers have never yet been answered and that no reign lasts forever, have begun to calculate the probable duration of the present prosperous régime and to speculate on the character of his heir apparent."

Slosson then continued to say that the chemist has the same raw materials as those used by nature, and that he will some day be able to make any commodity needed by man. The possible exhaustion of the coal supply, therefore, did not alarm him.

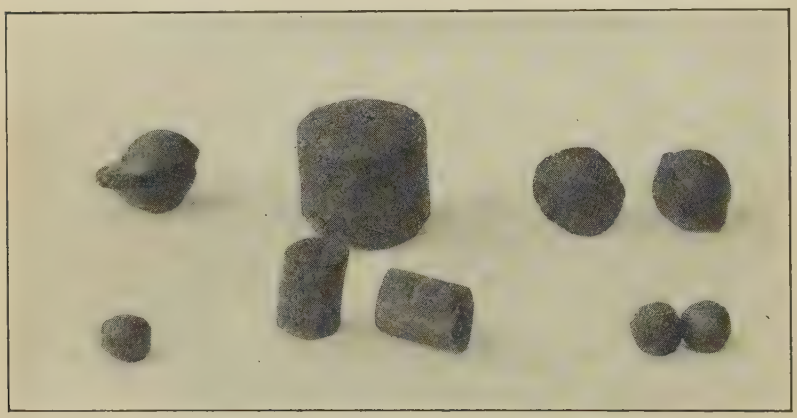
PULVERIZED COAL AS FUEL

Pulverized coal—coal ground to a fine powder and blown into the firebox of a boiler by air coming from a series of nozzles—has come to be used in many stationary steam engines. Henry Ford, among others, introduced its use into his plant at River Rouge, Michigan. The saving in money is great, and a greater degree of combustion can be obtained because of the increase in exposed surface of the coal. Ex-

periments are being made to adapt pulverized coal to use by sea-going vessels. When such adaptations are made, it will compete very favorably with, and may even surpass, oil as a fuel for ships.

BRIQUETS

Because of the scarcity of fuel in European countries, the use of fuel briquets has been common for many years. The necessity for using this type of fuel has not been felt in this country until the recent coal shortages, due chiefly to strikes, and the consequent rise in the price of coal. The chief difficulty so far has been the fact that most briquets do not hold a fire well when banked.



REPRESENTATIVE BRIQUETS MADE FROM COAL DUST

The following types of briquets have been made:

Powdered lignite compressed with binders (coal tar, pitch, or petroleum refuse).

Powdered coal compressed with a binder.

Sawdust compressed with a binder or held together with thin wire or cord.

Coke compressed into cakes, either with or without a tar binder.

PEAT AND LIGNITE

During the period when most of the coal of the world was formed, vegetation is thought to have grown more abundantly than at present. The plants were also of large size, as is evidenced by more than twenty-five hundred species of fossil remains of plants that have been found in coal measures. These have been studied by scientists, with the result that much information has been gathered about the type of plants that flourished during the Coal Period.

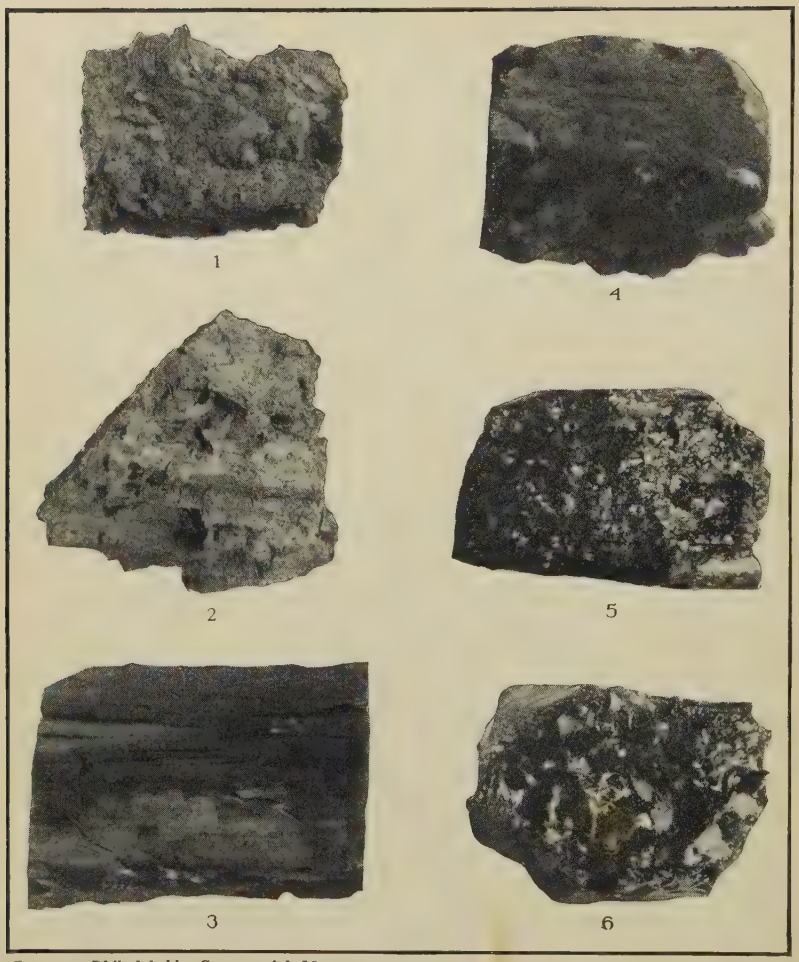
As the plants that grew abundantly on the earth while coal was formed crowded together in swamps, they gradually decomposed. The cellulose comprising the main part of the plant tissue was broken up, some such gases as marsh gas (methane) and carbon dioxide being given off. With sufficient covering of water to exclude the air, however, oxidation was reduced to a minimum, and the hydrogen-oxygen content of the molecule gradually became lower. This caused an increase in the percentage of carbon present.

The first stage in coal formation is the formation of peat. Peat is a substance in which it is sometimes easy to recognize its vegetable source. It has undergone, in the main, a darkening in color because of an increased percentage of carbon in it. Peat serves as a fuel in many countries in which coal is not as plentiful as in the United States.

When peat has been subjected to pressure, and consequent further loss of hydrogen and oxygen, for a long period of time, it becomes hard and coal-like, and dark brown in color. This product is called lignite or brown coal. Further decomposition results in the formation of the various coals.

About 20,000,000 tons of peat are used in Europe every year, but in the United States there are deposits estimated to contain 14,000,000,000 tons, an amount sufficient to supply Europe's rate of use of this material for 700 years.

Peat represents the arrested decay of vegetable matter.



Courtesy Philadelphia Commercial Museum

COAL—FROM PEAT TO ANTHRACITE

1, peat; 2, a piece of fuel which is "peaty" in some parts, but similar to lignite in others; 3, lignite; 4, semibituminous; 5, bituminous; 6, anthracite.

When plants fall upon dry soil, they are immediately attacked by bacteria and are changed to carbon dioxide and other inorganic compounds of no fuel value. But when the plant falls into water, it undergoes a different change. Most coals were once peats, but all peat may not become coal.

The largest peat deposit in this country is in Minnesota, and covers nearly 4,000 square miles or about 2,500,000 acres.

Peat burns freely when dry, and makes a hot fire. It is lower in heating value per pound than coal, but it forms no soot, is easily ignited, requires less draft, and has higher heating value than wood. It is a good emergency fuel, although the people of the United States have not yet been driven to its very extensive use.

In some parts of the world peat is used in considerable quantities as a domestic fuel. This is particularly true in certain rural regions of Ireland, Holland, and other of the northern European countries. It is usually the custom for people to cut blocks of turf from marshy bogs and stack it in the air for curing. In addition to this, there are some commercial firms that cut peat and dry it mechanically, and advertise it for sale.

Lignite or brown coal is higher than peat but lower than coal in the quantity of heat it can produce. Many European countries use considerable quantities of lignite as a fuel either directly or in the form of briquets. Even the United States, which has great beds of lignite in some regions, has begun a somewhat limited use of this fuel, although it has an abundant coal supply.

LIGNITE IN NORTH DAKOTA

Lignite coal is the chief raw material of North Dakota. The entire western part of the state and a small strip of northern South Dakota are underlaid with deposits of this material. In fact, there are 35,000 square miles of lignite beds, from 4 to 35 feet deep, which are workable in this region. Considering only the known lignite within 300 feet of the surface, North Dakota alone has about 516,000,000 tons. There are 185 lignite mines in operation in this state, and more will be opened as the demand for the material increases.

COKE

Coke has considerable application as an industrial fuel and has some use for household heating purposes. In times of anthracite shortage it is used somewhat more extensively for domestic purposes, although it is not so easily handled as hard coal.

In some parts of the world, coke is a common domestic fuel, it being considered uneconomical to waste the valuable by-products which go up the flue when soft coal is burned in domestic heating.

When soft coal is heated, it yields many products that are valuable for purposes other than fuels.

The following products are obtained from one ton of Pittsburgh coal, according to F. W. Speer, Jr., in *Chemistry in Industry*.

Total coke	1,500 pounds
Gas	11,360 cubic feet
Tar	12.4 gallons
Ammonium sulphate	25 pounds
Light oil	4 gallons

The coke produced may be used as a fuel, as it has a very high heating value, or it may be used—as is most of that produced in the Pittsburgh region—in the making of steel.

OTHER COAL BY-PRODUCTS

When coke is produced by heating soft coal, the gases, tars, and ammonium products sometimes go up in smoke, especially if the old-fashioned beehive coke oven is used. This device is still used to quite an extent. Before very long, however, it will be as extinct as the dodo, because improve-

ments on the so-called by-products coking oven, in which all of the products coming from coal are saved, are showing the wisdom of holding fast to all of the substances that come off when coal is heated. It has even been predicted that some time in the not far distant future, no soft coal will be burned at all, but will be distilled for the by-products, leaving coke to serve as a fuel.

Coal tar, a brown, smelly, viscous substance which used to torment the coal gas manufacturer because it clogged the gas pipes and was expensive to remove, is one of the most valuable coal by-products to-day. It yields benzene, toluene, naphthalene, anthracene, and other organic substances with equally euphonious names. These serve as raw materials in a number of modern manufacturing processes.

It was shown in 1821 that naphthalene (known to most of us as moth balls) could be prepared from coal tar. In 1845 Professor A. W. Hoffman of the Royal College of Chemistry in London discovered that benzene could be obtained from the same raw material. This scientist thereupon gave one of his students—a young man named Mansfield—the task of seeing how many materials he could obtain from coal tar. Mansfield did a remarkable piece of work, which showed to scientists all over the world that coal tar is a veritable storehouse of valuable compounds.

To-day the products derived from coal tar are used in the manufacture of many articles of war and peace, of necessity and luxury. Here are some of them:

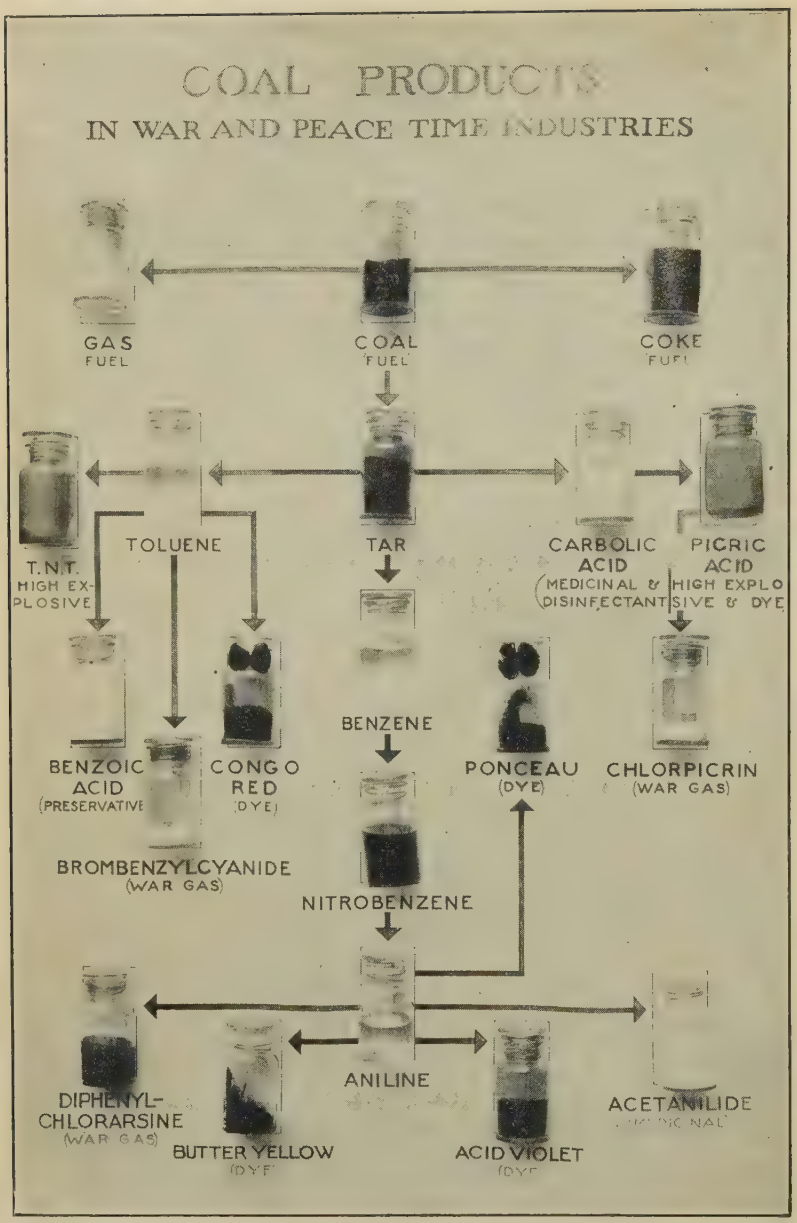
Dyes—More than could ever have been obtained from natural sources alone.

Drugs—Aspirin and many others.

Disinfectants—Particularly those of the carbolic and cresol type.

Perfumes, Flavoring Extracts—A considerable proportion of those on the market.

Insecticides, Wood Preservatives—Especially the creosotes.



A PARTIAL LIST OF COAL TAR PRODUCTS

Explosives—T N T and its relatives.

Saccharine—500 times sweeter than sugar.

Solvents—Such as those used in some lacquers and in many other common products.

Synthetic Resins—Bakelite and others of this type.

Ammonium compounds, another class of coal by-products, are extremely important. They are used as fertilizers, as electrolytes in certain kinds of batteries, in the dyeing and calico printing industries, and as sources of ammonia—our most important refrigerant.

Ammonium products are derived from coal by virtue of the fact that plant materials, from which coal has been formed, contain a small amount of proteins (nitrogen containing substances). These yield ammonia on distillation.

> There's hardly a thing that a man can name
> Of use or beauty in life's small game
> But you can extract in alembic or jar
> From the physical basis of black coal tar.
> Oil and ointment, and wax and wine
> And the lovely colours called aniline
> You can make anything from a salve to a star,
> If you only know how, from black coal tar.
>
> —*Punch*

PETROLEUM PRODUCTS

The origin of coal, peat, and lignite is established beyond much question. There is another series of carbon compounds of importance almost as great, the origin of which is not so well understood. This series of compounds is found together in a raw material that we call petroleum.

The word *petroleum* comes from two Latin words, *petra*, meaning "rock," and *oleum*, meaning "oil." This so-called rock oil is found between layers of sandstone in various geographic regions. America and Russia are among the leaders

Photograph by Ewing Galloway, N. Y.

GREAT GOOSE CREEK OIL FIELD IN TEXAS

in the production of this raw material. California, Pennsylvania, West Virginia, Wyoming, Indiana, Ohio, Oklahoma, Kansas, and Texas are among the leading oil-producing states in the United States.

Many theories have been proposed as to the probable origin

of crude petroleum. Some scientists believe that this substance was probably formed as the result of the interaction of certain inorganic substances such as water and highly heated carbides. Others believe that the slow decomposition of animal and vegetable matter produced crude oil. Both of these theories have the support of laboratory experiments.

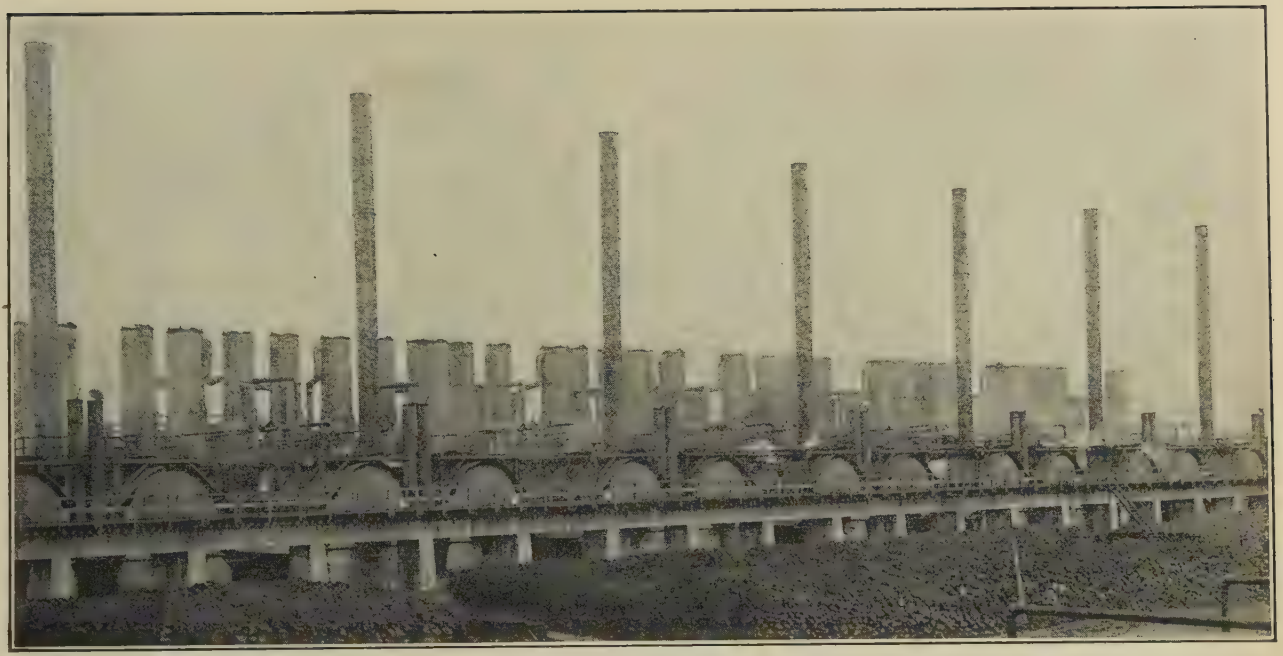
Here are a few of the products which can be had from crude petroleum by heating it in a still and collecting the fractions that come off at different temperatures, and then giving them a further chemical purification:

Light naphthas are used to dissolve rubber in the making of waterproof clothing, to dissolve varnishes for finishing our floors and furniture, and also as an airplane fuel. These distillates boil between 70 and 300 degrees centigrade, and are therefore dangerous to handle except by those who make handling them their business. Many a fire has been caused by the use of stove polishes that have light naphtha as the liquid ingredient.

Heavy naphthas include *gasoline* of high and low test. Some of the very volatile gasolines consist of mixtures of light and heavy naphthas. This is by far the most important petroleum product in this modern day when almost every man, woman, and child owns a car.

Burning oils are products higher in boiling point than the naphthas, and consist chiefly of *kerosene*. Formerly, when the kerosene lamp was the last word in illumination, the petroleum refiner made every effort to distil his product at such temperatures as to yield the greatest possible amounts of this fraction. Now this is crowded to a very small volume by the very much greater demand for motor fuel.

Intermediate distillates are products that are too heavy for use as fuels and too light for other purposes. The chemist plays a joke on them by subjecting them to a so-called cracking process, or a process by which the heavy carbon and hydrogen compounds are broken up into lighter ones having



OIL REFINERY

Here crude petroleum is turned into one hundred and one important kinds of everyday stuff.

vaporization and flashing temperatures suitable for use as motor fuels.

Heavy distillates include *lubricating oils* of all degrees of stiffness, from those suitable for the most sensitive of watches to those used to make heavy engines run smoothly.

Vaseline, which is a semi-solid product, is used in salves and creams.

The paraffin waxes are solid products which are frozen out of the heavy distillates by a process of chilling.

Tar and coke are left after the volatile products of the petroleum are eliminated by heating. The tar makes a good road binder, and the coke is used as a fuel to refine more petroleum.

THE ANTIQUITY OF PETROLEUM

"Petroleum has been known from the earliest times, and was to some slight extent used even by the ancients," writes Arthur D. Little in *Industrial and Engineering Chemistry*. He goes on to say:

> Baku, famous in antiquity for its sacred fires, is now more famous for its forest of derricks pumping oil. Here was struck the Droojba fountain, from which 2,000,000 gallons of oil a day spouted in a stream 18 inches in diameter, to a height of 300 feet, with a roar which was heard for miles. Can any other industry offer such a spectacle or one presenting such potentialities of sudden wealth?
>
> The great Roman architect, Vitruvius, writing in the time of Augustus, says:
>
> "Some waters flow through such greasy veins of soil that they are overspread with oil when they burst out as springs. For example, at Soli, a town in Silicia, the river named Liparis, in which swimmers or bathers get anointed merely by the water. Likewise there is a lake in Ethiopia which anoints people who swim in it, and one in India which emits a great quantity of oil when the sky is clear. At Carthage is a spring that has oil swimming on its surface and smelling like sawdust from citrus wood, with which oil, sheep are anointed."

The real romance of petroleum, however, began in America on August 28, 1859, when the Drake well came into production near Titusville, Pa. It was further stimulated by the classic report of Professor B. Silliman on the economic value of rock oil, in which, with marvelous prescience, he forecasts most of the industrial applications of petroleum.

The Drake well went down only 69 feet and yielded less than 30 barrels a day. It led, however, to such feverish exploitation of the Oil Creek district that before 1863 the number of wells exceeded 350. Some of these had records, for a time at least, of 1,000 to 3,000 barrels daily, and the market was so flooded with oil that 10,000,000 gallons are estimated to have run to waste in the absence of purchasers. To-day we are producing more than 700,000,000 barrels from about 300,000 wells, the deepest of which is down more than 7,500 feet.

In the porous strata of the oil sands, and beneath a protective cap of impervious rock, the oil and gas accumulate under pressure from the water below and move upward to the highest point which the conformation of the cap permits. The oil penetrates this cap and brings in the initial gusher. The burden of the industry is, nevertheless, carried by the modest, dependable 25 and 50 barrel well which stays on the job at all times.

GAS

Natural gas is of still more recent origin than petroleum. Professor Joseph F. James in 1889 for a popular science monthly wrote the following description of the gas boom in Ohio:

It is but little more than four years since there appeared among the economical products of Ohio and Indiana, a new force, which has worked a sort of revolution among manufacturers. The geographies used to say Ohio was noted for wheat, corn, and pork; now they must add petroleum and natural gas.

Rock-oil, or petroleum, has long been known to the world at large. So, too, has natural gas. The former was the early pioneer's panacea. So precious was it that it was soaked up from the ground by blankets, and was then wrung out and preserved. . . . It was known to the Chinese long years ago, and wells three thousand feet

deep, giving off great volumes of the material, were not uncommon. Burning springs had been found in Virginia in 1775, and were well known in the valley of the Kanawha River in the early part of this century. Fredonia, in New York state, was lighted by natural gas in 1824; while immense quantities of the precious fuel were at a later period, and before its great value had become recognized, wasted in the oil regions of Pennsylvania.

Notwithstanding these facts, no one suspected that there lay, concealed a thousand feet deep in the soil of Ohio and Indiana, such a wonderful source of power as has been discovered. Those who first sought for it were designated by the usual and familiar appellations of fools and cranks, just as the originators of the telephone, the telegraph, the locomotive, and the steam-engine had been before them. Recent events have proved the wisdom of the pioneers in the new field, and now portions of Ohio and Indiana are famous the world over as reservoirs of that wonderful product of Nature's laboratory, natural gas.

PETROLEUM FROM COAL

Because the world's supply of petroleum is small and unevenly distributed, many investigators have been working for the past few years on the production of petroleum products from coal. According to one process that has been developed, coal is treated with hydrogen gas under pressure by the use of catalysts such as iron, which serve as chemical agents to increase the speed of a reaction without being changed permanently themselves. As a result, the coal structure is broken down, the hydrogen attaches itself to the various parts, and substances identical in structure with petroleum distillation substances are formed.

Friederich Bergius, a German chemist, in 1913 was the first to work out a practical method of hydrogenating coal. In his early experiments, Bergius allowed hydrogen to act upon finely powdered coal at a temperature of about 450 degrees centigrade, and at a pressure of several thousand pounds per inch. Iron compounds and other catalysts were used. Eighty-five per cent of the coal was decomposed into liquids and

gases. Plants for the conversion of coal into oils by the Bergius method have been erected at various places in Germany and in other countries.

TIMES CHANGE

About 1920 Requa, one of America's leading authorities on oil, said: "For petroleum there is no satisfactory substitute as a lubricant; its exhaustion spells commercial chaos or commercial subjugation by the nation or nations that control the future source of supply from which petroleum will be derived. There is but one escape, and that is the discovery of some substance, now unknown, that will efficiently and economically lubricate the machinery of the nation."

In 1927 Hans Tropsch, a German coal chemist, said: "All of the products of natural petroleum have been made in great purity from coal."

Another method of making petroleum from coal is the so-called water gas method.

Water gas, which is a mixture of hydrogen and carbon monoxide, can now be used to make all of the useful compounds present in petroleum. These syntheses are brought about by the use of catalysts. Much of the work in this field is being done at the Kaiser Wilhelm Institute for Coal Research at Muelheim-Ruhr, Germany. Dr. Hans Tropsch of this institute came to the United States in 1927 to give a series of lectures at the American Chemical Society Institute of Chemistry held at the Pennsylvania State College. Dr. Tropsch stated in his lectures that it was highly probable that petroleum found in nature may have been formed from gas mixtures containing carbon monoxide and hydrogen, by the agency of some catalyst which happened to be present.

As a matter of fact [said Tropsch] we find in nature gases which contain carbon dioxide, carbon monoxide, and hydrogen. . . . Thus, gases collected from a crater on Mount Pele, after allowing for air

sucked in at the time, consist of 50 per cent carbon dioxide, 5 per cent carbon monoxide, 18 per cent methane, and 27 per cent hydrogen—a gas mixture such as we have often obtained in our syntheses. The catalyst required for the reaction, particularly iron, is to be found everywhere, and the activating substance, i.e., alkali, is also present.

There are, therefore, indications existing from which we can conclude that at least part of the natural kinds of crude oil was formed inorganically with the aid of catalysts. From this we can conclude that even to-day, under favorable conditions, crude oil is being formed.

FROM ONE FUEL STUFF TO ANOTHER

What next?

When man first learned how to build fires, he used wood as his chief fuel, because wood was on top of the ground and plentiful.

When, centuries and centuries later, wood began to show signs of playing out, man dug into hillsides and took out coal, a product which, quite by accident, he found would burn. Later he sent pipes far down into the ground and brought forth oil and gas.

When the old reliable natural fuels proved insufficient in quantity for all mankind everywhere, some folks relied upon the use of peat and lignite, natural fuels upon which nature had not worked long enough to produce the best results.

When all the natural fuels, including peat and lignite were not keeping everybody warm and doing all of the industrial work necessary, fuels formerly wasted—powdered coal, powdered lignite, and wood sawdust—began to be saved. Briquets were made of some of these, so as to improve them both in ease of handling and heating value.

In order to extend the use of gas to a greater number of people, artificial gas of many kinds was made, such as coal gas, water gas, acetylene and pyrofax.

In order to increase the quantity of petroleum available,

coal has been subjected to a process by which it has been broken down into simpler substances identical with petroleum products in structure and behavior.

Whenever coal becomes less plentiful than petroleum, we will turn the latter into the former by some chemical process or other if coal is needed at that time. A process of this sort has already been worked out.

Man has even resorted to the use of water power and the sun's rays as a source of heat, and as the need arises, he will draft into service other reservoirs of natural energy not even thought of as yet.

CHAPTER VII

A SAFETY MATCH

The fire in the flint
Shows not till it be struck.
—SHAKESPEARE

IT was hundreds of centuries after man found out about how to use fire before he learned how to build fires easily. The old methods of stick rubbing and using the various forms of the fire drill were tedious enough, as every boy scout can testify, to have stimulated a hunt for something better. In fact, people were constantly on the lookout for improved methods of fire lighting, and many discoveries were made as the years went by. But all of them seem antiquated indeed to us, with modern safety matches at a penny a box.

THE TINDER BOX

Until the eighteenth century, we find that fires continued to be started by striking flint and steel together and allowing the sparks to fall into a tinder box. Tinder consisted of a bunch of charred linen and cotton threads and scraps, which could be set afire very easily. A thread covered with sulphur was placed among the tinder. This could be removed when it was lighted, and carried wherever it was wanted. It was frequently the custom for a person to carry a metal box having two compartments, one for the steel and flint and the other for the tinder. The original plain piece of steel came to be elaborately decorated, and many persons of means owned sets in which the steel was fitted with a handle of bronze, gold, or ivory, and the flint was replaced by the more expensive agate.

Even down through the early American colonial days, a tinder box was as important an article of household use as a box of matches is to-day.

THE DIP SPLINT

The first improvement over the old-fashioned tinder box was the dip splint. The dip splint, which was the progenitor of the modern match, consisted of sticks dipped in a mixture of melted sugar and potassium chlorate. The match was ignited by dipping it into concentrated sulphuric acid. This was carried in a bottle or was contained in one compartment of an elaborately ornamented case, with the splints themselves in another compartment. These matches were quite expensive, and those sold in fancy cases brought very high prices. About a pound, nearly five dollars, is said to have been the price of 100 matches without any case at all. Think of matches at a nickel apiece!

Matches of this first type were not particularly popular, and they never came into very general use. They had many drawbacks. Sulphuric acid—as those of us who have become too intimate with it know—is not friendly to clothing, and it also produces severe burns on the flesh. The sulphuric acid became too weak for effective use after a time, because it absorbed moisture from the air. Then, too, many an accident was said to have occurred because of the fact that if a match which was dipped into the acid failed to work, the economical owner often placed it back in the case with the others. The acid that adhered to this stick frequently came into contact with the neighboring matches, with the result that the whole case burst into flame.

From this dip splint, the match that would ignite as a result of friction rather than chemical heat had its origin. The friction match or lucifer, however, was not possible until one of the chemical elements—phosphorus—was discovered.

THE DISCOVERY OF PHOSPHORUS

Phosphorus was discovered in 1669 by a merchant named Hennig Brandt of Hamburg, Germany. Brandt occupied his spare moments with a study of alchemy and the practice of medicine. In his efforts to produce gold, he one day prepared some white phosphorus—a substance hitherto unknown. The new substance attracted unusual attention and was considered very valuable. Brandt held the method of preparing this substance (which was unique because it would take fire spontaneously) a secret.

In spite of the fact that Brandt carefully guarded the secret of how he prepared this yellowish-white brittle solid, which he called *phosphorus* after the Greek word for "Morning Star," three other scientists worked until they found out how to prepare the element also. Two of these were Germans, Krafft and Kunckel. The third was none other than the Englishman, Sir Robert Boyle, the first of the modern chemists.

Some of the incidents surrounding the discovery of phosphorus read like a book of fiction. One of the discoverers, Johann Kunckel, wrote a book entitled *Laboratorium Chymicum* (first edition, 1716), in which he described his own labors in the preparation of this element. On a certain trip to Hamburg, about 1677, Kunckel relates that he was told of a certain merchant-alchemist-physician named Brandt, who had produced a material that glowed continually in the dark. A friend introduced the two men, and Kunckel stayed around Hamburg in the hope of learning more about this new material. Brandt, however, put him off from day to day with one excuse and another.

Meanwhile, Kunckel wrote to an acquaintance named Krafft, at Dresden, and told him of the state of affairs. Without telling Kunckel of his intentions, Krafft immediately betook himself to Hamburg and began secret negotiations with Brandt for obtaining information about the new substance. He gave

Wissenschafft. Erfahrenheit u. Verstand von allen Sachen,
Solten diesen ehrlichen Mann numehro unvergleichlich machen.
Und die Wahrheit, die das Ziel meines Hertzens ist,
Soll mir helffen, Ehre und Ruhm JOHAN KUNCKELN.

JOHANN KUNCKEL

One of the discoverers of phosphorus and inventor of "Wonder Glowing Pills."

Brandt 200 Reichsthalers on the condition that he should make him some of the new substance but should not inform any one about the transaction or give any one else the secret.

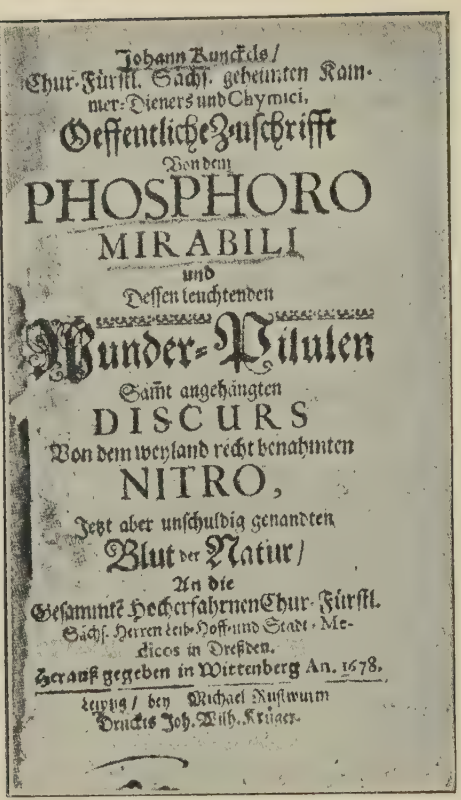
Not knowing even that Krafft was in Hamburg, much less

that he was visiting Brandt, Kunckel went again to Brandt's home. Brandt excused himself for not inviting him in on the grounds that his wife was ill. Furthermore, he told him that he had lost the art of producing the substance, since recent efforts had proved fruitless.

Kunckel thereupon prepared to leave Hamburg, but chanced to meet Krafft on the street before he departed. Krafft assured him "by stone and bone" that it was hopeless to try to get any information from Brandt because he had the reputation of being extremely stubborn. After Kunckel's departure from Hamburg, he wrote to Brandt and asked him once more for information concerning the new glowing substance. Brandt replied as before, that he had lost the art of preparing it himself. Kunckel persisted with letters, and Brandt finally replied that by a special dispensation of Providence he had rediscovered the art, but that he could not disclose the secret. The former thereupon wrote again, stating that he would spare no pains to make the discovery himself and that he considered himself under no obligation to any one in the event that he should succeed.

Meanwhile, Krafft began displaying his product at the court of Hanover and in other important cities. The fact that he was making money out of his exhibitions displeased Brandt, who wrote to Kunckel to try to negotiate with him, telling him of the fact that Krafft had paid him 200 Reichsthalers, but that he had broken with him entirely. He added that he expected Kunckel to pay him, even if he should discover the trick himself.

Kunckel finally succeeded in making the discovery, but he refused to pay Brandt anything because he had given him no assistance. Meanwhile all three men independently displayed their product before the various crowned heads of Europe, exciting considerable wonder and making some money. Krafft, who was quite hard up financially, sold his secret to all who would pay him five Reichsthalers.


Johann Kunckels /
Chur-Fürstl. Sächs. geheimten Kam-
mer-Dieners und Chymici,
Oeffentliche Zuschrifft
Von dem
PHOSPHORO
MIRABILI
und
Dessen leuchtenden
Wunder-Pilulen
Samt angehängten
DISCURS
Von dem weyland recht benahmten
NITRO,
Jetzt aber unschuldig genandten
Blut der Natur /
An die
Gesammte Hocherfahrnen Chur-Fürstl.
Sächs. Herren Leib-Hoff- und Stadt-Me-
dicos in Dresden.
Heraus gegeben in Wittenberg An. 1678.
Leipzig / bey Michael Russworm
Druckts Joh. Wilh. Krüger.

TITLE PAGE FROM KUNCKEL'S BOOK ON PHOSPHORUS

This page describes the spiritual and physical wonders of this new discovery.

Kunckel put the phosphorus that he prepared to a use other than that of entertainment. A material of such remarkable characteristics was considered by him as undoubtedly having exceptional medicinal properties. He therefore produced "Glowing Wonder Pills" of this element, and prescribed them indiscriminately for all sorts of ailments for grown-ups and children alike. He even coated some of the pills by allowing them to stand in solutions of gold or silver.

"One or two of these pills taken evening and morning," said

Kunckel, "will save a man, with the help of God, from all fear of apoplexy or of other sudden sickness during the day. They counteract all noxious and poisoned airs and are a right antidotum against the pestilential poison. They strengthen and support the vital spirit in man. . . ."

One is constrained to believe that Kunckel must have prepared one of the atomic forms of phosphorus other than white phosphorus, which takes fire spontaneously, and which would have killed any one in short order who swallowed it. Even so, the thought of giving any of the forms of phosphorus as a medicine is appalling indeed.

It is interesting to note in passing that Kunckel fails to tell in any of his works how he finally succeeded in preparing phosphorus. From the records of other chemists of his time, however, we gather that both he and Brandt prepared the element from urine and sand by distillation in a clay retort. The phosphates produced by this distillation were reduced to elementary phosphorus by the carbonaceous material present. Later, scientists used phosphate rock and carbon with the same results.

Sir Robert Boyle put the phosphorus that he produced to a useful purpose. He showed how, if it were placed carefully between two pieces of heavy paper, it would cause the paper to ignite. This was much handier than any of the previous methods of starting a fire, but it had to be done carefully because a severe burn resulted if the tiniest particle of the element came in contact with the skin. Boyle later invented a crude phosphorus match which had a considerable sale.

The price of phosphorus was exceedingly high for a hundred years after it was discovered, because the method of making it was quite tedious. In 1771 Scheele, the great Swedish chemist, found out how to produce this element easily from its cheapest compound—the calcium phosphate of bones—and its price immediately dropped.

LUCIFERS

The word *lucifer*, used to refer to the friction match, means "light bearer." An Englishman by the name of John Walker is credited with the invention of lucifer matches in 1820. The first real friction match which was practical made its advent in 1832. It consisted of a splint dipped in potassium chlorate and antimony sulphide. It was ignited by drawing it sharply through two pieces of sandpaper. About two years later phosphorus was substituted for the antimony sulphide, and the match needed less friction to ignite it. Later, the composition was still further improved by the introduction of other materials as substitutes for the potassium chlorate.

PHOSSY JAW

Much trouble was caused in the manufacture of white phosphorus matches because of the so-called occupational disease known as phossy jaw. This disease was found to be very common among workers in the match factories. The disease manifests itself first as a serious affection of the jaw, but results in its final stages, in death. All attempts to stamp out the disease by attention to the sanitary conditions of the factory failed.

Fortunately, in 1845 Professor Schroetter of Vienna found out that white phosphorus can be changed into a red variety of the same element if it is heated in a stream of carbon dioxide for thirty or forty hours.

Red phosphorus is exactly the same element chemically as the white, but it varies in physical attributes. It consists of a maroon colored powder which does not ignite spontaneously and which exhibits many other remarkably different characteristics. This difference in properties between these two so-called allotropic forms of the same element is due to a difference in the arrangement of the atoms within the molecule.

THE PASSING OF THE WHITE PHOSPHORUS MATCH

For a time after the discovery of a red variety of phosphorus, which possessed few of the disagreeable properties of white phosphorus, matches were made in some plants of this new substance. Later it was found that the sesquesulphide of phosphorus, a compound of sulphur with this element, was even better than the element itself. The Diamond Match Company of this country patented the process covering the use of this compound, but later turned the patents over to the United States Government in order to assist in the stamping out of the use of white phosphorus in the match industry. By the early part of the twentieth century all civilized countries had banned by law the manufacture of the white phosphorus match.

HOMES CONTINUE IN SPITE OF THE DISCOVERY OF MATCHES

The discovery of fire led prehistoric men to give over their nomadic habits and settle down in one spot where the family fire could be guarded against the tragic event of its going out. Now that matches are so common, one might expect people to go back to a wandering existence. In the meantime other inventions and discoveries have made the home so comfortable that no one would consider returning to the wandering habits of the cavemen, even though a couple of dozen matches can be purchased for a penny, patent friction lighters can be bought at the ten cent store, and a fire can thus be built quickly anywhere. For that matter, one does not even have to use a match in cooking a meal nowadays, because the electric stove gives heat without a fire.

ICE IN ITS NATURAL STATE

Man no longer has to depend upon nature for his refrigeration during the hot months. The old industry of ice-cutting is rapidly giving way to modern methods of making artificial ice.

CHAPTER VIII

COLD STUFF

Seek roses in December—ice in June,
Hope, constancy in wind, or corn in chaff.
—Byron

ROSES in December and ice in June was Lord Byron's idea of something extremely improbable. If this poet had lived in the present day of greenhouses and ice plants, instead of a century ago, he would surely have looked for a more striking way of illustrating the unlikely. At the present time, roses are just as likely to grace our tables on Christmas Day as on Flag Day, and ice never clinks more musically in our glasses than on the Fourth of July.

It is no longer a fact that people find continual fault with

the weather but fail to do anything about it. The human race has declared its independence of the seasons, and it can now produce heat and cold at will.

Man discovered the means to keep warm centuries before historical records were kept. It has only been within recent times, however, that he has found out the means of keeping things cool. The story of the manner in which he has conquered the way to make the thermometer fall at will is an important part of the history of man's mastery of stuff, and it is also closely bound up with the history of progress in political and trade relations between countries.

To be sure, there are a few scattered instances in which ancient peoples made attempts to cool themselves. In a few Asiatic countries it was the practice to fill sacks with snow from the mountain tops and to haul these on the backs of mules to nearby cities. In order to make this snow last as long as possible, it was stored in straw-lined pits dug in the ground, and covered over with twigs. This snow was used by members of the wealthy classes to cool foods and drinks. In ancient Greece and Rome the same practice was recorded in a few instances, although at no time was the food cooled for any reason other than to make it tastier. The ancients had no idea that cold aided in the preservation of foods.

In India, the monotony of twelve months of scorching weather so goaded the natives of some regions that they found out early how to make ice artificially.

BACON'S EXPERIMENT

The first man to see the possibility of using cold as a means of preserving perishable foods was Francis Bacon, Baron Verulam, who lived from 1561 to 1626. Bacon was an English statesman, writer, and scientist, who was extremely displeased that the Europeans of his time had made no progress beyond the ancients in the use of snow and ice. He once said:

"... heat we have in readiness in respect of fire, but for cold, we must stay till it cometh or seek it in deep caves or high mountains...."

During the latter part of his life, Bacon devoted himself to the study of science, a study which his earlier political activities made impossible. When he was sixty-five years old he decided to find out by actual tests whether or not food could be kept from spoiling by keeping it cool. As he was driving near London one snowy day, he ordered his coachman to stop in front of a farmer's cottage. Here he purchased a chicken from the housewife, and he himself assisted in stuffing the fowl with snow.

While Bacon was performing this test he became seized with a violent chill and had to be removed to the house of a friend. As a result of this exposure he contracted bronchitis, and died a few days later. He did not pass away, however, until he noted the success of his experiment and caused it to be described in writing.

It would seem that the death of so distinguished a man from such a cause would have attracted the attention of many people to his experiment. But no one continued Bacon's tests, and no important application of refrigeration was made until about one hundred and seventy-five years after his death.

BEGINNINGS OF THE ICE INDUSTRY

The real beginning of the ice industry came in 1805. At this time, Frederick Tudor, a wealthy citizen of Massachusetts, decided to see whether or not ice could be shipped to the warmer parts of the earth. At this particular time, yellow fever was raging throughout the West Indies. The towns and cities were being depopulated in some regions. The officers and crews of many European vessels were likewise being swept off by this hideous disease. The need of ice, which was very keenly felt in this emergency, appealed to Tudor. He there-

fore set about to cut ice from a small pond situated on his property. This he hauled to the nearest port and loaded on a brig called *Favorite*.

The people of Tudor's time made a great deal of sport of what they considered to be his wild and visionary undertaking. It had been only a short time before this that Timothy Dexter, a business man of New England, had brought down the laughter of the whole country upon himself by shipping a large consignment of warming pans to these same West Indian islands. During the cold winters of New England these warming pans were very useful for taking the chill out of the bed before retiring. That the natives of the tropical West Indies would not find them equally valuable for this same purpose did not occur to Dexter, since he had never made a study of their climate. He was, therefore, nothing short of foolishly lucky when all of his warmers sold at good profits after all, because the West Indians found that they would serve admirably as molasses ladles.

Tudor, on the other hand, knew that he was making no foolish venture. He had studied conditions in these islands, and he appreciated what ice would mean to people of the tropics, especially when they were suffering from a scourge of fever. Since he was of a stubborn disposition, the ridicule that he received only made him the more determined to build up an ice trade with different parts of the tropical world.

Tudor's first shipment of ice carried by the *Favorite* was landed on the island of Martinique. Although the experiment was a financial failure, Tudor was more than satisfied with results. Since he had already made a fortune in the salt industry, he could afford to lose money on the first of his ice ventures. The loss which he suffered resulted from the melting of some of his ice after it was taken from the ship because there was no place to store it before it could be sold. He knew that ice houses built at the port where the ice was delivered would remedy this difficulty.

After Tudor's first venture in the ice business, he began to extend his opportunities for "harvesting" ice. He bought strips of land along some of the principal New England rivers and lakes, and built ice houses on them. He made a few other trips to the West Indies, but his business did not begin to flourish until certain European governments became interested in his undertaking. Soon after the War of 1812, thoughtful men of Great Britain came to realize the value of ice as a means of preserving food and of adding to the general comforts of life. They realized the advantage to the tropical English colonies which would result from the delivery of ice to their ports regularly. As a result of this, the British Government entered into an agreement with Tudor. According to the agreement, he was to be relieved of the usual heavy port duties and was to have no competition, provided he should guarantee regular deliveries.

Tudor consequently built ice houses in the ports of certain of the West Indies islands then owned by England, and began his fulfillment of the contract. Spain thereupon made him a similar offer, and he added Cuba to his ice route.

While business with the British and Spanish possessions in the West Indies was opening up, Tudor had meanwhile seen the possibilities of selling ice to his fellow countrymen. Although this trade began to be of some importance in all parts of the country, the southern states offered the best market. Ice houses were built at such centers as Savannah, Charleston, and New Orleans, and distribution of ice began to be made over the entire South through these ports.

Tudor's greatest venture in the ice business came in 1833 when he began to ship to Britain's far-away colony of India. Calcutta, India's greatest port, was 20,000 miles from Boston by the route traveled in that day. The journey required six months. The first shipment of 200 tons resulted in a financial loss for the same reason that the first load to the West Indies had not paid. This trial trip showed, however, that ice could

be packed in a ship in such a way that it would not melt during a six-months' voyage. Having proved this, Tudor built ice houses at Calcutta, and thereafter carried on a steady trade with that port.

CRUDE ARTIFICIAL ICE

The ice that Tudor shipped to India at this time had to compete with a product that the natives had been making artificially for ages past. The inhabitants of India were the first people to originate a method for making ice, and their process was quite an interesting one.

They commenced their preparations for making ice by marking out a large rectangular piece of ground and removing the soil from this to a depth of about two feet. The earth at the bottom was then allowed to dry thoroughly in the sun. Dry sheaves of rice straw were laid on the bottom of the pit, and loose straw was placed over these.

After the excavation was prepared, shallow, unglazed earthen vessels were placed on the straw and filled with water. These dishes were only about one and one-half inches deep and were so porous that they became moist throughout. These pans were left exposed to the night, and layers of ice a fraction of an inch thick were formed in them.

It is probable that the natives themselves could not explain why ice should form in a tropical region by the application of this process. Some of their ancestors had accidentally stumbled on the method and had passed the secret down from generation to generation.

The reason is easily understood nowadays. During the night the breezes hasten the evaporation of a part of the water by carrying off the vapor as fast as it is formed. Heat is needed to change water into water vapor, and some of this heat must come from the water that is left. The water thus cooled is not warmed again by the ground, because the dry straw upon which the dishes rest is a nonconductor of heat. The water

that soaks into the porous vessels likewise evaporates, and this helps to cool the dishes. The more the water evaporates, the cooler become the remainder of the water and the dish. When the process of evaporation continues long enough, therefore, the remaining water becomes cold enough to freeze, and a thin layer of ice is formed on its surface.

At the time when Tudor made his first shipment of ice to India, quite a number of natives were making their living by manufacturing ice by their ancient method. To all appearances the market was not oversupplied, however, since they continued to make ice even after the American ice king's trade was well established in their country.

Even to-day, when modern ice plants are to be found in some parts of India, the primitive method of making ice is still followed in a few instances. Perhaps it is because the ice makers who follow this ancient method are unwilling to abandon a process that their fathers handed down to them, or perhaps because the amount of ice made in modern ice plants in India is not yet large enough to supply the needs of all of the people. Ice is indeed one of the most important articles of everyday use in that tropical country. Many travelers who visit that part of the world mention the ice peddlers of the cities of India, who sit cross-legged at the side of the street with a few blocks of their stock tied up in dirty sacks reposing between their knees, while the fierce heat pours down and melts their profits before their very eyes.

THE ARTIFICIAL ICE INDUSTRY

Even though the ancient inhabitants of India had discovered long ago that ice could be made artificially, it was not until 1775 that the first small machine for making ice was invented. This machine was invented by Dr. William Cullen, a Scotch physician and scientist. Cullen worked on the old principle followed by the natives of India, that water becomes cool when

a part of it evaporates. He went a step further, however, and figured that water will evaporate more rapidly in a vacuum than in the air, even when the wind is blowing. He therefore rigged up an airtight vessel with an air-pump attached. When he pumped the air out of the vessel, he found that the water evaporated very quickly. When the space inside the vessel became filled with water vapor, however, he discovered that the water would stop evaporating. This trouble could only be remedied by placing some substance in the vessel which would absorb water vapor. He used sulphuric acid for this purpose, and succeeded in cooling off the water sufficiently to produce a small amount of ice.

Fifty-five years after Cullen's invention, Sir John Leslie, another Scotch scientist, invented a more elaborate apparatus for making ice by a scheme similar to that of Cullen. A score of other inventors offered improvements on the methods of Cullen and Leslie, but none of the devices proposed were capable of making ice in any but very small quantities.

Finally, in 1834, John Perkins, an American scientist living in London, patented a device which was the forerunner of our modern ice-making machinery. In Perkins' machine, ether was pumped under pressure into a coil of pipe, where the pressure was removed and the ether was allowed to evaporate. This coil was submerged in a solution of salt, which became quite cold when the ether was vaporized. This cooling of the salt water took place because vaporization is always a heat-absorbing process.

A small tank of pure water was submerged in the brine container in Perkins' machine. Since salt water freezes at a much lower temperature than pure water, it was possible to reduce the temperature of the salt water low enough to cause the pure water to freeze while the salt water remained unfrozen.

The chief difference between Perkins' original plan and the one in use to-day is that compressed ammonia has been substi-

SHIPPING FISH WITH DRY ICE

Sloppy ice-salt mixtures no longer need to be used in shipping food products.

tuted for ether. It was Michael Faraday, a great English scientist, who first discovered that ammonia gas can easily be liquefied by the combination of both cold and pressure. He found that when the pressure was removed, the liquefied am-

monia boiled off rapidly, forming ammonia gas. The faster the liquid boiled, strange to say, the colder it became. This was of course because vaporization is a heat-absorbing process. It remained for Edmund Carré, a Frenchman, to use ammonia for the first time in 1850 in a machine for making ice.

In a modern ice-making machine, ammonia gas is compressed by machinery until it becomes a liquid. The vessel in which the ammonia is liquefied tends to become hot as the liquefying process goes on, and it must be cooled off with running water. The liquid ammonia then passes into coils of pipe submerged in tanks of salt water. The ammonia vaporizes in these coils, and cools the brine. Pure water in cans placed in the brine is thus frozen in twenty-four to thirty-six hours. The ice comes out of these cans in the form of clear, smooth blocks. About one pound of ammonia can freeze three pounds of ice, and the ammonia can be used over and over again.

The artificial ice industry did not begin to reach any degree of commercial importance until 1880. It was in our own southern states that the industry first began to assume importance, since it was cheaper to make ice at the place and time it was needed than to ship it a long distance and store it for months. Ice harvesting is still quite an industry in the northern part of the United States, however, and it supplies much of the local market in places where it is carried on.

WHY ICE COOLS

Whether our ice boxes are filled with natural or artificial ice, however, the great need of this material for preserving foods during warm weather is appreciated by all of us. The ice in our ice boxes keeps foods cool and thus helps to prevent bacteria from causing it to spoil.

Ice keeps the refrigerator cool because it melts. Melting is a heat-absorbing process, just as vaporizing is. When ice melts, heat is absorbed from its surroundings. Patent ice

blankets, which are designed to be spread on the ice in a refrigerator and to retard its melting, are therefore of less than no value, since ice that does not melt does not refrigerate.

TRAVELING ICE BOXES

Although the ice boxes that we have in our homes are a very great item in the saving of foods, they must yield second place in importance to refrigerators which travel about and carry perishable foods from one part of the world to another. The simplest traveling refrigerator is probably the wooden box in which the progressive farmwife brings to market her pound blocks of butter packed in chopped ice. Contrasted with this are the refrigerator freight cars and steamship compartments fitted up to transport all kinds of foods from one corner of the continent to another, and from one end to the other of the entire globe.

The first traveling refrigerator of any size to be used was a freight car in which meat was shipped in 1857 from Chicago to New York. After this experiment, it was found to be cheaper to send meat in iced cars than to ship livestock. This was an important discovery, because previously it had been impossible to secure any meat except that which was butchered very near at hand.

The first refrigerator ship to make a successful trip across the ocean was a special vessel called the *Frigorifique*, fitted out in 1870 by Charles Tellier, a French engineer. Tellier, who was at that time a man of forty-eight years, had already devoted much of his life to the study of refrigeration. The *Frigorifique* was supplied with chambers particularly well suited to the shipping of meat. The refrigerator rooms of this vessel were equipped with machinery similar to that of our modern cold storage plants, rather than with ice bunkers, since ice had proved unsatisfactory for keeping the low temperatures required for long trips.

ECONOMIC IMPORTANCE OF COLD

The *Frigorifique* was built especially to bring meat from the Argentine, where cattle were plentiful, to France, where meat was scarce. Meat was carried from France to Buenos Aires on the first trip made by this vessel. When the ship reached the Argentine port, a great banquet was given to celebrate its arrival. The meat which had been preserved during the three months of the voyage was served up together with fresh meat from the country, and guests were unable to tell the difference between the two kinds.

The success of the first voyage of the *Frigorifique* was a matter for great rejoicing by natives of the Argentine, for they knew that their meat could now be marketed anywhere in the world.

After the first trip of the *Frigorifique,* cold storage equipment was installed in many other ocean-going vessels. A particularly good trade in frozen meats was set up between England and her colonies. This benefited Australia and New Zealand especially, since they were now able to sell beef and mutton to their mother country, whereas previously they had been able to ship only hides, tallow, and wool. The inhabitants of the British Isles were equally benefited, because the price of meat was forced down and the poor people were able to buy more meat than they previously could afford.

COLD STORAGE AND HEALTH

The application of cold storage, or the process of cooling brine by the evaporation of ammonia, using the brine as the cooling agent, has completely changed the eating habits of people all over the world. More people than before can now eat meat, because it can be shipped in refrigerator cars or ships from the place where it is produced to any part of the world. Had it not been for the invention of cold storage, the

great packing-house industry could never have been developed. The great size of this industry can be understood when we consider that the Chicago stockyards alone handle more than twenty million head of stock in a year.

The sea, which has only begun to furnish food to any large number of people since the development of refrigeration, now supplies the world with a large quantity of meat. Although people who lived inland could formerly obtain only canned or dried sea food, they can now have fish that is almost as good and as inexpensive as it is on the coast.

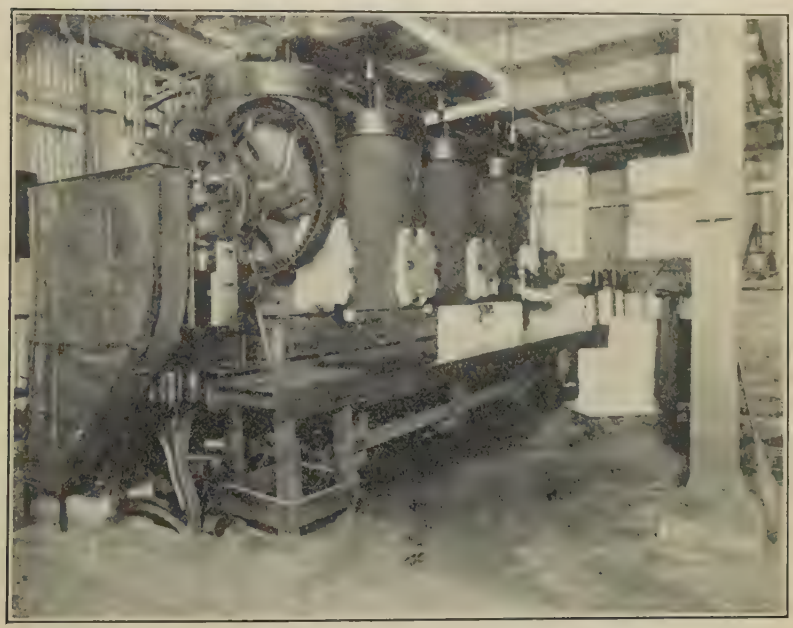
Eggs can now be shipped from one extreme corner of the earth to another, and they can be kept from the time of the year when they are plentiful until the season when they are scarce. Eggs from China now come into competition in New York markets with those from New Jersey and Pennsylvania.

Fresh milk can now be included in the daily diet of old and young, whether they live in the city or in the country. The increase in the amount of milk used throughout the world has meant much for the health of the human race. Milk supplies materials that help to build up the tissues of the body; it contains energy-giving substances; it is rich in mineral constituents, particularly those needed in bone-building; and it is rich in those factors called vitamins which play so important a part in the proper growth and development of the body. Without modern methods of refrigeration, fresh milk could only be had in rural districts.

Refrigeration has made it possible for people living in the north to have fresh fruit all the year round. What this has done toward increasing the vigor of the northern nations cannot be computed. Formerly, people living in cold climates who could not secure fruit and vegetables during the long months of winter were sometimes attacked by a disease called scurvy. Physicians studied for a long time to find the cause of this malady. They finally discovered that it was due to the lack of a vitamin contained in certain fruits and vegetables

and in some other kinds of fresh food. Since refrigeration has made it possible to have fresh foods all the year round in all parts of the world, scurvy has become practically unknown.

The change brought about in our habits of eating by the introduction of cold storage can well be understood when we think of the banana. The first bananas were brought from South America in 1870. These were put on display as a



DRY ICE PLANT

curiosity. To-day, more than fifty million bunches of this fruit are brought to this country each year. We are now as familiar with the banana as with the apple, although few of us have seen the plant on which it grows.

ICE CREAM

Ice cream is another article of food that has become common along with artificial ice and cold storage. Ice cream was

invented late in the eighteenth century by a London confectioner named Gunton. Dolly Madison was the first person to introduce this delicacy into America when she served it at the White House at a reception, where it met with great favor. After the introduction of ice cream into this country, Nancy Johnson, the wife of an American naval officer, invented an ice cream freezer for home use. Ice cream is now eaten the year round in all parts of the country, although it still has its greatest popularity during the summer months. The people of New York City alone eat 11,000,000 gallons of ice cream each year.

HOUSEHOLD REFRIGERATION PLANTS

In all man's efforts to get control of the ups and downs of temperature, he has gone through the usual stages in the development of a new industry. First he takes from Nature whatever she has to give for his particular use. Next he improves upon the natural article. Finally he works out some plan for making an artificial substitute which is quite as good or even better than the natural product.

In the ice industry, man has gone even further than is his usual custom. His first step, of course, was the taking of ice from Nature's streams and lakes and the storing of it for his own use. This was followed by his discovery of methods of keeping the water supply as pure as was possible, so as to keep down disease. Then came the discovery that artificial ice, which was the equal and perhaps the superior of the natural product, could be made. His final achievement was the discovery of a substitute for the substitute for natural ice.

Instead of using ammonia to cool brine which freezes ice, he now applies cold storage, in which brine is used directly to cool the substance that he originally cooled with ice.

Even in our household refrigerators, we have begun to apply the cold storage principle. It is now possible to equip our kitchens with iceless ice boxes in which foods are kept cool by

wire. We are advised by experts to have our refrigerators electrified. As one person suggests:

> Why the gentle ice-man chide?
> Have your box electrified.

In the household iceless ice box, an electric motor compresses either sulphuric dioxide or carbon dioxide. Ammonia, the refrigerant used almost exclusively in the larger types of equipment, is not satisfactory for the small machine because too high a pressure is needed to liquefy it.

The compressed gas is then caused to expand in a coil surrounded by a brine solution. The brine, which is thus chilled, is then circulated through coils of pipes surrounding the cooling chamber.

REFRIGERATION FROM HEAT

Not only electricity, but gas, can be used to cool brine in a household refrigerator. One of the most efficient automatic refrigerators on the market is run by a gas flame. Now that man has learned to lower the temperature by means of heat, what can he not expect to accomplish next?

The following description of a gas refrigerator is taken from the *Industrial Bulletin* of Arthur D. Little, Inc.:

> The idea of using a comparatively cheap fuel, such as gas, to produce refrigeration for the household seems paradoxical, but it may be recalled that whenever a motor-compressor unit is producing refrigeration a coal pile is somewhere being consumed to produce the electrical energy for the motor. Refrigeration by the direct use of gas thus eliminates the long chain of intermediate apparatus between the coal pile and the motor compressor. . . .
>
> The principles of the design and operation of the gas fired unit belong in general to the absorption type of refrigerating machine, which was in fact one of the earliest refrigerating systems to be developed in the last century. . . . A solid absorbent which can absorb, at ordinary temperatures, large quantities of a suitable refrigerant and retain but little at a higher temperature is necessary to simplify the old type of absorption machine.

In the modern gas fired refrigerator, a refrigerant, such as ammonia, may be used with a solid absorbent, such as charcoal or silica gel. The application of heat drives the gaseous refrigerant out of the absorbent, where it condenses as a liquid in the refrigerating coils. Cooling the absorbent restores its gas-absorbing powers, with consequent evaporation and absorption of the refrigerant. When the refrigerant evaporates in the coils, the temperature is reduced.

As a matter of fact, one of the best evidences of man's mastery of materials may be found in a new combination cook stove–ice box. In this device the same fuel that raises the temperature in the upper compartment is used to lower it in the refrigerator underneath.

A REFRIGERANT FROM SMOKE

It would seem about as unlikely that one could squeeze blood from the proverbial turnip as that ice could be made from smoke. But frozen carbon dioxide, or dry ice as it is called, is made in this way. Coke is burned under a forced draft, so that the carbon of which it is largely composed changes completely to gaseous carbon dioxide. This is purified and cooled, and compressed to a liquid under a pressure of about one thousand one hundred pounds per square inch. The gas is then allowed to evaporate rapidly through a very small nozzle into a confined space. The loss of heat energy resulting from this rapid evaporation is sufficient to freeze the substance.

The heat for running the compressors needed in the process comes from steam, which is generated by the heat from the coke that is being burned to form the gaseous carbon dioxide.

BEATING ICE AT ITS OWN GAME

Dry ice is joining cold storage and electric and gas refrigerators in giving keen competition to ice. As a matter of fact,

dry ice can outdo ordinary ice at the game of being chilly, since it is about 144° Fahrenheit colder than water ice.

Dry ice or solid carbon dioxide is now marketed extensively for shipping ice cream, candy, butter, cheese, and eggs. Special cartons are made for each of these products, and only a small quantity of the refrigerant is used in each carton. The small pasteboard container in which pints or quarts of ice cream can be carried home are coming to be quite common.

The economy of using dry ice for long distance shipping is appealing to many people. Dr. H. Killefer, writing in the *Industrial and Engineering Chemistry Journal,* says:

> In the transportation of ice cream between Philadelphia and New York, experience has shown that 200 pounds of solid carbon dioxide replaces 3,000 pounds of water ice and 600 pounds of salt, an efficiency ratio of 15 to 1. In the shipment of frozen fish from New York to Detroit, 17,000 pounds of water ice and 10 per cent of that weight of salt are ordinarily consumed per car, whereas the same quantity of fish may be shipped over the same route in a frozen condition with the use of only 1,200 pounds of solid carbon dioxide, and furthermore, the carbon dioxide is all loaded at the beginning of the trip and does not require frequent replenishment. . . .
>
> Not only is there a saving in actual refrigerant used, but ordinary practice with water ice requires that the car be taken off service approximately 20 per cent of the time of the journey for re-icing, and this is avoided by carbon dioxide icing with a corresponding saving in investment charged.
>
> The large amount of water ice required by a car adds to the weight of nonpaying freight and reduces the space available for pay freight. The very low temperature of solid carbon dioxide and the factor of safety which this introduces into refrigeration makes it possible for a car to carry as much as 50 per cent more perishable freight than its present accustomed load.

Truly, inventive man puts the stuff that he finds or creates to every possible use.

CHAPTER IX

MEASURING THE UPS AND DOWNS OF THE WEATHER

What is it molds the life of man?
The weather.
What makes some black and others tan?
The weather.
What makes the Zulu live in trees
And Congo natives dress in leaves
While others go in furs and freeze?
The weather.
—HUMPHREYS, *Weather Proverbs and Paradoxes*

ABOUT the only pleasure any one can get from extremes of weather is the satisfaction of saying that to-day is the coldest day in eighteen winters, or that yesterday was the hottest day ever recorded in the history of the weather bureau. There is a reason why the weather furnishes us with such a pleasant and ever ready topic of conversation at the breakfast table, on the street corner, or over the grocer's counter. It is the fact that the weather is really of very great importance to all of us. Many things depend upon the weather, such as the laying in of fuel, the buying of ice, the preservation of foods, the putting on or taking off of winter underwear, and the planting and harvesting of crops.

Man is not so completely at the mercy of the weather as he once was. He can build fires, make artificial ice, and turn on an electric fan. During the time when he was slowly working out ways of getting the best of the weather, he was also inventing many devices for measuring weather conditions. Chief among these are the thermometer, which measures degrees of heat, and the barometer, which measures the pressure of the atmosphere.

THE AIR THERMOMETER

The word *thermometer* comes from two Greek terms which mean "a measurer of heat." The first instrument that was used to indicate temperature and to measure its changes was made about 1592 by the famous Italian scientist Galileo. Galileo's instrument was an air thermometer which worked on the principle that air contracts when it is cooled and expands when it is warmed.

Galileo's air thermometer consisted of a hollow glass bulb about the same size as a hen's egg, to which a glass tube about the diameter of a straw and about 18 inches long was attached. When he set up the instrument for use, he warmed the bulb with his hands and turned it upside down so that the end of the tube dipped into a vessel of colored liquid. As soon as the bulb cooled, the air inside the apparatus contracted, and the liquid rose in the tube. If left undisturbed, the colored liquid would go up and down the tube as the air was thereafter cooled and warmed.

The very earliest practical use of Galileo's thermometer was for taking the temperature of sick persons. This use was first thought of by an Italian physiologist of Galileo's acquaintance, whose full name was Sanctorius Sanctorius Justipolitanus. Sanctorius, as he was commonly called, was the first to discover that all persons in good health have the same body temperature. He found thereafter that this crude instrument could be used to tell when a person was not in normal condition. In one of Sanctorius' writings he said: "I have applied it [the thermometer] to the determination of the warm and cold temperature of the air and of all parts of the body, as well as for testing the heat of persons in a fever."

The structure of the clumsy air thermometer of Galileo had to be changed somewhat to adapt it to the reading of a person's temperature. It could not be inverted, because the liquid would have spilled out of the open vessel that the stem was

placed in. Since it was the temperature inside of the body and not that of the outside that Sanctorius wanted, he constructed thermometers in which the upper part of the tube was curved, so that the bulb, which he reduced in size, could be inserted in the mouth of the patient. Even with his improved model, it was almost necessary to bring the patient to the thermometer instead of taking the thermometer to the patient.

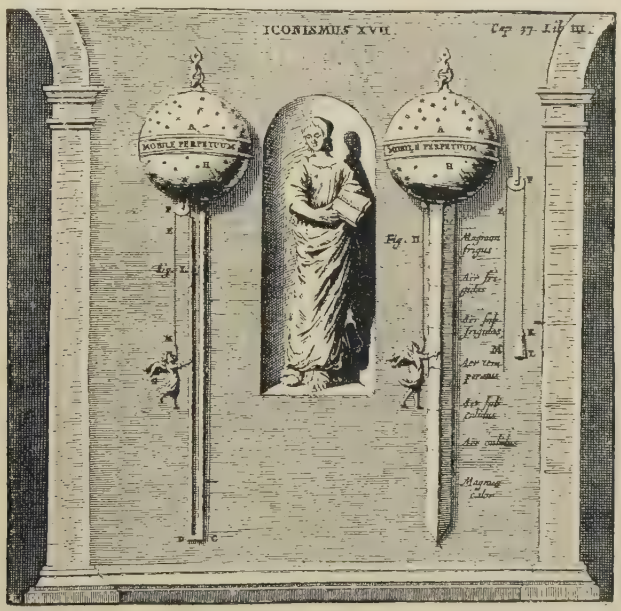
Not very long after the invention of the air thermometer, an error was found which at first had not been understood. The instrument sometimes showed the temperature of healthy people as changing from one time to another. The reason for this was the fact that the liquid in the outer vessel was acted upon by the pressure of the air. On days when the air was heavy, the liquid was forced up in the thermometer. When the air pressure was light, the liquid came down a certain distance. These changes in pressure were not at first considered, but all differences in the height of the colored liquid were thought to result from temperature changes only.

THE DUKE OF TUSCANY'S THERMOMETER

The first thermometer that was independent of the pressure of the air was made in 1654 by the Italian nobleman, Ferdinand II, Grand Duke of Tuscany. His thermometer depended not upon the expansion of air, but upon that of a liquid. The liquid used was a crude kind of alcohol, and it was placed in a sealed tube. The alcohol was colored so that it could be seen, and certain points on the tube were marked with colored enamel. During the next fifteen years Ferdinand and a group of Italian scientists who worked on the alcohol thermometer improved it until it became quite a valuable scientific instrument.

The use of thermometers spread from Italy into other countries of Europe. The first collection of these instruments to travel to another country was sent by Ferdinand to the Queen

of Poland. The queen's secretary later sent one of these Italian thermometers to an astronomer living in Paris, and in this way the fame of these instruments was spread over the continent. The Italian city of Florence forthwith became the center of the thermometer manufacturing industry, and a century later Florentine thermometers were in use by men of science all over Europe.



ANCIENT THERMOMETERS

These early instruments for measuring degrees of heat and cold were more decorative than they were accurate.

The early thermometers were not very satisfactory, however, because the scales with which they were marked were not all alike. One scientist living at that time said that he could not find that any effort was made by thermometer makers to agree on a uniform method of marking the divisions on their instruments. As a result, it was possible to say only that one thing was hotter than another, but nothing more. Many men of the

time were anxious to adopt a definite scale so that it would no longer be necessary for a scientist to send along the thermometer he used when he wrote to another scientist about an experiment.

STANDARDIZATION OF THERMOMETERS

Robert Boyle, the great English scientist, was among the first to attempt to standardize thermometers. Boyle placed a thermometer in oil of anise and marked the height of the alcohol at the point at which he found the oil to freeze. With this as his starting point, he divided the stem into degrees according to fractions of the total volume of the alcohol. This system was not adopted by other scientists, however, because it was complicated and not altogether reliable.

Robert Hooke, an English scientist of Boyle's time, used another system. He filled thermometers with alcohol "highly tinged with the lovely color of cochineal," and marked them at the point at which water froze. He then made divisions on the stem in much the same complicated way as that suggested by Boyle. In his writings concerning the success of thermometers made in this way, Hooke said: "I have brought sealed thermometers to a great certainty and tenderness, for I have made some with stems above four feet long in which the expanding liquor would so far vary as to be very near the top in the heat of summer, and very near the bottom at the coldest time of winter."

Many other men of Boyle's and Hooke's time came forward with suggestions for making uniform thermometer scales. These suggestions all had to do with the adoption of one fixed point, and ideas in this matter ran all the way from the temperature of a deep cellar to that of the highest heat of the hottest day of summer.

It was not until some one had the idea of taking two fixed points and dividing the space in between into degrees of equal

size, however, that a uniform thermometer scale became a possibility. One of the earliest inventors to follow this scheme placed his lower point at the freezing point of water, and his upper at the melting point of butter. His scale read somewhat like this:

Hot (melting point of butter) ..... 10°
Temperate ..... 0°
Cold (freezing point of water) ..... —10°

FAHRENHEIT'S THERMOMETERS

The first inventor to construct a thermometer having a reliable scale based on two fixed points was Daniel Gabriel Fahrenheit, a young German scientist. In the thermometer which Fahrenheit perfected after much labor, he used mercury instead of alcohol. He took for his lower fixed point the coldest temperature that he was able to obtain with a freezing mixture of ice and salt. This he believed to be the greatest cold possible, and he expected this to remain the lower limit of the temperature scale for all time. For the upper fixed point he took the temperature of the human body, which he considered as unchanging from generation to generation. He divided the space between these two points into 96 degrees. He extended the scale above the upper point, making all of the degrees the same size. It was merely a matter of chance, therefore, that the boiling point of water happened to come at 212°, and the freezing point at 32°.

It was later found that Fahrenheit had incorrectly measured the normal temperature of the human body. This was found to be 2.6 degrees higher than that obtained by his original measurements. This error did not interfere with the scale he had made, however, and the freezing and boiling points of water were kept at 32° and 212°, respectively.

After the fame of Fahrenheit's thermometers began to spread abroad, he established himself in the manufacturing business

in Holland, to which country he had moved. He made scientific apparatus in general, but thermometers were his specialty. His thermometer tubes were made of a superior grade of glass produced especially for him at two glass-blowing plants, one at Berlin and one at Dresden.

Fahrenheit's thermometers soon found their way all over Europe. They penetrated even into such remote places as Iceland and Lapland, where a lower extension was obliged to be added below the zero point. Even in milder climates, people found that they had winter weather in which the temperature fell below zero.

This disproved at once the inventor's idea that his ice and salt mixture was as cold as anything could possibly be. The extension of the scale was not difficult, however, and degrees of the same size were added below the zero point, and this point was not changed.

At 40° below zero still another difficulty was met. This was the fact that mercury froze at that point. Alcohol thermometers with the same Fahrenheit scale were therefore used in extremely cold countries. Alcohol is still employed to-day in thermometers for measuring low temperatures because it does not freeze until it reaches 166° below zero, while mercury freezes at 40° below.

Except in the event of very low temperatures, however, mercury is better than alcohol. An alcohol thermometer, for example, cannot be used for measuring the boiling point of water, for alcohol boils at 172° Fahrenheit. Mercury, on the other hand, does not boil until it reaches 630° Fahrenheit, which is high enough for all of the usual demands made upon a thermometer.

Mercury also has other advantages which recommend its use in thermometers. It does not wet the glass, and hence the position of the top of the liquid is very distinct. It changes its volume very quickly with changes of temperature. It is opaque and easily seen in the tube. The expansion of mercury

is less for a certain rise in temperature than alcohol, which makes it possible to make mercury thermometers of a smaller size.

THE CENTIGRADE THERMOMETER

There are two thermometer scales in use in this country, both of which we may meet quite frequently. The Fahrenheit scale is in common use in homes, school rooms, office buildings, and for other everyday purposes. For scientific work, however, this has been replaced by a much more convenient scale called the centigrade. The centigrade thermometer scale is extremely easy to use because the freezing point of water is placed at zero, and the boiling point at 100°.

As far back as 1694, an Italian mathematician named Carlo Renaldini proposed to take the freezing and boiling points of water as the two fixed points of the thermometer and to call these zero and 12° respectively. This suggestion was not followed, however, and it was soon forgotten. In 1742 Andrew Celsius, a Swedish astronomer, modified the method suggested by Renaldini, and made the boiling point of water zero and the freezing point 100°. Other scientists of his time reversed the scale, and the centigrade (the scale having 100 degrees between the boiling and freezing temperatures of water) has become the thermometer scale used in exact scientific work all over the world.

In most of the countries of Europe the centigrade thermometer has come to be used for all purposes, both scientific and everyday. In English-speaking countries, however, the awkward Fahrenheit scale is still used for all except scientific work. Fahrenheit was an accomplished man of his time, and he produced an instrument that was far in advance of others existing before his day. His instrument, however, is much less convenient in every respect than the more recently devised centigrade thermometer. For this reason there is much to be said in favor of adopting the latter scale for all purposes in

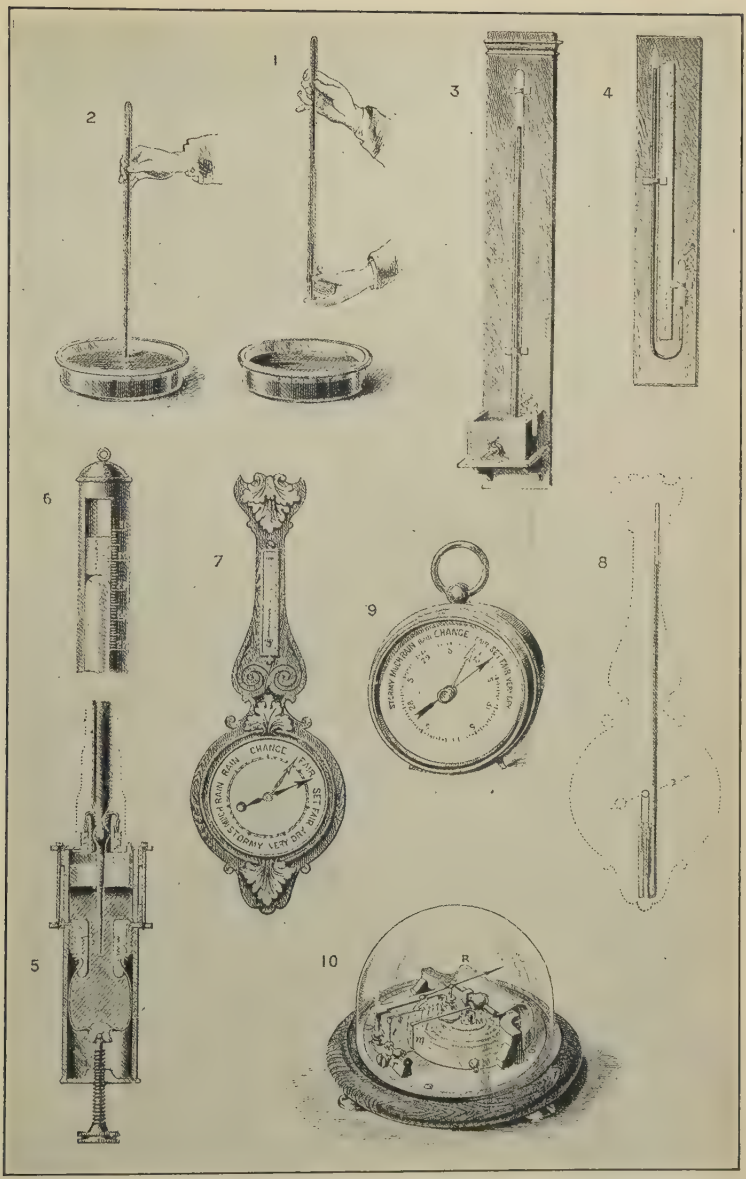
English-speaking countries, so that the same scale will be used for both everyday and scientific purposes and all countries will be uniform in their temperature measurements.

MANY KINDS OF THERMOMETERS

At the present time the thermometer has a larger number of practical uses than may at first occur to us. Thermometers for taking the temperature of sick persons are even more important than they were in the time of Sanctorius. Modern clinical thermometers are much smaller in size and therefore more convenient to handle than the first clumsy air thermometers. They have the added advantage of being able to record the highest temperature that has been reached during the examination of a patient. Such thermometers have a reduction in the size of the bore. When the mercury has reached the highest point, however, it does not return through the narrow part of the tube, but remains until it is shaken down by a skillful twist of the wrist. Thus there is no danger that the mercury will go down while the doctor removes the thermometer from under the patient's tongue and reads it.

The small thermometers used by doctors are examples of numerous special temperature-taking instruments devised for particular uses. Besides alcohol and mercury thermometers, neither of which would be suitable for some uses, there are thermometers made of solid metals, the expansion and contraction of which register the temperatures of some special things. Among these instruments are the maximum and minimum thermometers by which the weather man tells the highest and lowest temperatures reached during a certain period. The weather man also has thermometers that write a continuous record on a roll of paper revolved by a clockwork device.

The agricultural scientist has thermometers several feet long to show the temperature deep down in the soil. There are also thermometers for the blind, thermometers that turn in a



VARIOUS FORMS OF THE THERMOMETER AND BAROMETER

1, 2, Torricelli's experiment with tube full of mercury; 3, barometer in its simplest form; 4, barometer with bent tube and scale; 5, 6, Fortin's portable barometer, with structural details; 7, common wheel-barometer or weather-glass; 8, internal structure of weather-glass; 9, aneroid barometer; 10, internal mechanism of aneroid.

fire alarm, thermometers that turn upside down at a certain hour of the day or night and register the temperature at this time, and thermometers that may be upset when they are sunk to certain depths in the ocean and thus record the temperature of the water at a certain point.

THE BAROMETER

The barometer is not so common an instrument as the thermometer, but it is quite as important in finding out what the weather is likely to do, and also in making many scientific studies. It is a device for measuring the pressure of the air. The story of the events that led to its invention is interesting and is worth telling here.

Aristotle and all the philosophers that lived in olden times explained many natural happenings by saying that "nature abhors a vacuum." These ancient men of learning noticed that space was always filled with some material substance, and that the moment a solid substance was removed from a certain place, air or water always rushed in to take its place. They were acquainted with the common pump, and they knew that water came up when the piston was worked up and down. They thought that the water rushed up to fill the space left vacant by the piston. This belief concerning nature's abhorrence of a vacuum was held for at least two thousand years.

During the early part of the seventeenth century, however, some Italian workmen were hired to sink a well of unusual depth for the Grand Duke of Tuscany. When the well was sunk, they attached a lifting pump such as they ordinarily used. To their surprise they could not make the water rise more than 32 feet. They took pains to make their joints tight and to perfect their machinery in every way, but 32 feet was the greatest height to which the water could be made to rise.

These workmen were told to explain their difficulty to Galileo, the greatest scientist of the time. Galileo at first

explained the happening by saying that there was a limit to Nature's horror of a vacuum, and that this limit was the pressure of a column of water 32 feet high. He later realized that this explanation was not a good one, and he began to work on the problem in a scientific way. Galileo, however, was then an old man and had suffered a great deal of persecution because many of the facts that he had previously discovered were different from the established teachings of the time. He did not have the energy to solve the question that the workmen put to him, but he turned it over to his pupil, Torricelli.

TORRICELLI'S EXPERIMENT

It was after Galileo's death that Torricelli discovered why water could not be made to rise more than 32 feet in the Duke's well. His explanation was that, when the piston of the particular kind of pump they were using was pulled up, the water rose because something pushed it up, and not because Nature abhors a vacuum. He reasoned that the air pushing down upon the surface of the water in which the end of the pipe was placed must be the force that made the water rise.

Torricelli tried by a simple experiment to get additional proof that air exerts pressure. Since a tube 32 feet long would have made it necessary for him to have cut a hole in the roof of his house if he was to carry on his work indoors, he hunted around for a means of simplifying the test that he had in mind. Instead of using water, therefore, he decided to use mercury, a liquid 13.6 times as heavy as water, which would thus show the same results with a much shorter tube. He selected a glass tube about four feet long, and sealed one end with the heat of a flame. He then filled the tube with mercury, held his thumb over the open end, and inverted it in a basin of mercury. When he removed his thumb from the end of the tube, the mercury dropped until it stood at a height of about twenty-eight inches. Since this was $\frac{1}{13.6}$ as high as the col-

umn of water that was made to rise in the Duke's well, Torricelli reasoned that the weight of the air is sufficient to support a column of water 32 feet high, or the same weight of any other liquid.

Torricelli's experiment made quite a stir all over Europe. Convincing as his test was, however, the scientists of the time refused to believe that his explanation of the behavior of the mercury was the correct one. The two-thousand-year-old belief as to Nature's horror of a vacuum was so deeply rooted that it could not be easily dislodged. Instead of carrying out experiments to test the truth or falsity of the theory that air exerts pressure, the men of his time tried to settle the argument by debate. Torricelli unfortunately died of a fever while he was yet a young man, and he never knew that his discovery was to become famous in the history of science.

PASCAL'S WORK

Blaise Pascal, a French scientist living from 1623 to 1662, heard of Torricelli's test and believed in the truth of his reasoning. He decided to put an end to the stupid arguments of the men of the time by performing other experiments along this same line. "If," said Pascal, "it really be the weight of air, under which we live, that supports the column of mercury in Torricelli's tube, we shall find by transporting the tube upward in the atmosphere, that in proportion as it leaves below it more and more air, and has consequently less and less above it, there will be a less column sustained in the tube."

To prove this belief, Pascal carried a Torricellian tube to the top of the highest church steeple in Paris, and found that the height of the mercury in the tube became slightly less. Since this did not entirely satisfy him, he wrote his brother-in-law, M. Perrier, who lived near the high mountain of Puy-de-Dôme, and asked for his help. He gave this relative exact directions for setting up the apparatus and carrying it to the

top of the mountain. Perrier carried out his instructions carefully, and found that the mercury column was a little over 3 inches lower on the top of the mountain than it had been in the valley, ". . . which," he wrote, "ravished us with admiration and astonishment." Pascal studied this experiment still further and found that altitudes could be measured exactly by means of a Torricellian tube.

Before long it was discovered that the height of the column of mercury varied at the same place at different times. The barometer (pressure-meter, as it came to be called) was then used to predict weather as well as to measure altitude. It was found that when the mercury rose in this instrument, the air was heavy and the weather was likely to be fair. When it fell, the air was light and stormy, or unsettled weather was likely to follow within a short time. Great declines in the barometric pressure often occur in advance of earthquakes and other serious natural disturbances. A cyclone or heavy wind storm never occurs except in a region of low air pressure.

Thus the barometer and the thermometer have become extremely valuable aids to human comfort, since they help in the foretelling of storms and other natural disturbances. When it is known that unusual weather conditions are coming, people can be prepared for them.

ANCIENT SPINNING AND WEAVING

This is the first historical record of spinnng and weaving. (From a painting from the tomb of Beni Hassan.)

CHAPTER X

TEXTILES FROM TEST TUBES[1]

What stuff wilt have a kirtle of?
—SHAKESPEARE

"WHAT stuff wilt have a kirtle of? I shall receive money o' Thursday," said Falstaff to Doll Tear-sheet in an expansive moment, in Shakespeare's "Henry IV."

When the events of this play were supposed to have taken place, there were but four textile fibers from which one could fashion a kirtle. These fibers were all found in nature and they were wool, linen, silk, and cotton. At the present time these natural fibers are used in larger quantities than ever before. In addition to these, a large number of synthetic fibers —the products of the chemical laboratory—has been placed at our disposal.

The synthetic textile fabrics are so attractive that the modern woman would hardly be disturbed at all, so far as her personal wardrobe is concerned, if the supply of natural fibers

[1] This chapter is an elaborated revision of a paper read by the author July 26, 1927, before the Institute of Chemistry at State College, Pennsylvania. The original paper was published in the *Chemistry Leaflet*, Vol. 1, No. 14, Jan. 14, 1928. Another paper was published under this title in the *Journal of Chemical Education*, January, February, March, and April, 1929.

were cut off altogether. Man, on the other hand, still depends almost entirely upon wool for his outer garments and cotton for his underwear; but he draws heavily upon rayon for his ties, socks, and hatbands. Then, too, the recent work that has been done toward the making of synthetic wool substitutes, and the recent interest displayed by at least some men in rayon underwear, may indicate that the entire human family might some day be clad entirely with textiles from test tubes.

Whether or not it ever comes to pass that all mankind clothe themselves entirely in synthetic products, the chemist will ever stand ready to make whatever textile fibers are needed to piece out nature's supply. By placing artificial products on the market at very low prices he has already done more than any other single agency toward making a democracy of all the peoples of the world.

EARLY CLOTHING

In reviewing the history of synthetic fibers it is interesting to go back to the earliest times and consider briefly the history of textile fibers in general.

When members of the human race first began to clothe themselves (we will leave the philosopher to speculate as to whether heat, cold, modesty, rain, or insect pests prompted them to do so), they took from Mother Nature whatever she had to offer for the purpose. The skins of animals, the leaves of trees, tall grasses—all were doubtless used at some time or other by the various races of the earth in the early stages of their progress.

Skins.—Whatever variations may have occurred among different tribes, the skins of animals undoubtedly afforded the first costuming material of widespread use. Because skins used without treatment of some sort soon became stiff and harsh and were also likely to putrefy, the process of tanning was worked out through centuries of tedious rule-of-thumb

methods, and was an old industry when histories began to be written.

Felts.—From the earliest times, leather has held first place for sandals and shoes, but as a general clothing material it early proved itself to be rather inadaptable. Some inquisitive prehistoric member of the human race, however, found out that he could take the woolly fibers from the skins of the ancient forerunners of our modern sheep and beat them together into a matted felt. This felt made a better garment than the hide from which it came. The felting properties of wool are due to the presence on the fiber of a covering of microscopic scales which hook together and form an entangled mass.

EARLY SPINNING

But even felt is not ideal for making garments for general wear. It must have been the deft fingers of some prehistoric woman that first discovered that wool fibers could be twisted into a continuous thread. The first threads that those investigative fingers spun, however, may have remained curiosities for a long time before it was found that woolen threads could be woven into cloth.

Woolen garments were quite warm and comfortable for cool climates and must have given considerable satisfaction to ancient peoples, as they do even to-day. It was only in comparatively recent times, however, that the chief cause of the warmth of fibers became known. This warmth is also a result of the microscopic scales that cover the fibers, mentioned above in connection with felting. Underneath each minute scale is a tiny space in which air is entrapped. Since air is a poor heat-conductor, it helps wool to serve as an excellent protection against cold.

The ancients, of course, knew nothing of microscopes or of the physical structure of the wool fiber, but they accepted the fact that wool was warm, and made the most of it. About the

chemical structure of wool the ancients likewise knew nothing. We cannot boast of knowing very much about this point even to-day. We are fairly sure that the wool fiber consists of one or a number of protein substances, which we group together as one substance and call *keratin*. To this little understood substance we assign the empirical formula $C_{42}H_{157}N_5SO_{15}$, because it is in accord with the elementary analysis of the fiber. It remains for some chemist—perhaps for some present-day student of chemistry—to determine just how these atoms are arranged within the molecule.

But back to the ancients.

Although wool was used by the Egyptians, it was considered unclean by that race and was used only to make outer cloaks. The Egyptian priests would not permit a fiber of it to be used for any part of their clothing. Even the common people seldom wore it next to their skins, and the outer woolen wraps that they wore had to be left outside the temple when they went in to worship. Woolen garments were further discriminated against by never being buried with the dead.

LINEN

Because of their aversion to wool, the Egyptians were therefore never noted for their woolen fabrics. They were, however, very famous for their linens. When Solomon, at the height of his glory, wished to import the finest textile fabric made anywhere in the world, he sent for Egyptian linen. It has never been rivaled in evenness of thread, for it was without knot or break. Egyptian linen thousands of years old is still in existence, and it is said to excel in texture even the finest of modern linens, although it is darkened with age.

Linen differs from wool in that it comes from the plant instead of the animal world. Linen fibers are derived from the inner bark of the flax plant, where they occur as bast fibers. Their function is to serve as conveyers of plant foods from

one part of the stem to another. They consist chemically of a substance called cellulose, to which the modern chemist has assigned the formula $(C_6H_{10}O_5)_x$. The x in this equation is another confession of ignorance on the part of the chemist as to how many of the $C_6H_{10}O_5$ units are found in the entire molecule.

Flax fibers are separated from each other by soaking the flax in water for some time. A process of rotting or, as it is sometimes called, retting, takes place. This makes it possible to pull the fibers apart and prepare them for weaving.

Unbleached linen is tan in color. It may be bleached by spreading the fabric on the grass in the sunlight for some days. In modern times it has been found possible to bleach linen more quickly by a chemical process, but the fabric bleached in this way loses something of its wearing qualities.

TREE WOOL

Cotton is another common textile fiber of plant origin. The wild plant from which it is procured came originally from India. When Herodotus, a Greek historian, visited India about the fifth century B.C., he described cotton in the following unique manner: "And further, there is a tree which grows wild there, the fruit whereof is wool exceeding in beauty and goodness that of sheep. The natives make their clothes of this wool tree."

The description that Herodotus gave to the cotton plant was spread about by word of mouth among the various countries of Europe for many generations. Even after the inhabitants of India had begun the extensive cultivation of the cotton plant and were exporting cotton to Europe in large quantities, Herodotus' description of the source of this plant was still being repeated. Like many a tale that grows with the telling, this description came to have no resemblance to the original. People began to call the cotton plant the "lamb tree" and to

tell fictitious stories about the way lambs grew on its branches. Each night, so ran the tale, the branches of this tree would bend down, and the lambs would graze on the grass. The next morning they would straighten up again. As late as the fifteenth century, a writer on scientific subjects published a book in which he included a picture of a lamb tree drawn to suit the popular notion of what a cotton plant should look like. Later,

THE LAMB TREE
An ancient conception of the wool-bearing animal—or plant.

when Europeans began to travel more extensively, visitors to India saw the cotton plant, and the old fable about its nature ceased to be believed.

Although the cotton fiber comes from a different part of the plant than do the linen fibers, its importance to the plant itself is no less great. This fibrous growth which was present on the seeds of the wild plant from which cultivated cotton descended, served as a means of scattering the seed by the agency

of the wind. This made it possible for seeds to find lodgment in suitable soil, and thus helped to reproduce the plant. When cotton came to be cultivated, man selected his seeds from plants whose pods were filled with the most plentiful and best fibers. By a careful selection of seeds year after year, growers of the cotton plant succeeded in producing much better fibers than those of the wild cotton plant.

Cotton is almost identical with linen in chemical composition, a fact which makes it practically impossible to distinguish these fibers one from another by chemical means. They can easily be distinguished from each other, however, by means of the microscope. Linen is composed of cylindrical cells cemented together end to end, and resembling bamboo when magnified. Through the microscope, cotton appears like a collapsed, spirally twisted rubber tube. This natural twist makes it quite suitable for spinning.

EARLY HISTORY OF SILK

Silk is another fiber that has been used for spinning cloth from very ancient times. Silk, like wool, is of animal origin. It is spun *as long continuous fibers* by certain kinds of worms. The worm wraps these fibers about itself into a cocoon which serves to protect it during its period of change from the worm to the moth stage. Each fiber consists of two filaments surrounded and cemented together by a gum-like covering.

The Chinese were the first to discover that cocoons could be boiled in water and the fibers unwound and used for making cloth. They found that a species of worm which lived on mulberry leaves produced especially satisfactory fibers, while another, living on oak leaves, was also usable.

The cultivation of the mulberry silkworm began almost three thousand years before Christ. The first home of the industry was China. The idea of cultivating silkworms is credited to the Empress Si-ling, who lived about 2700 B.C. Si-ling was the wife

SILKWORM CULTURE
(From an old Japanese manuscript.)

of Emperor Hoang-Ti, whose reign is said to mark the invention in China of wagons, bows, and bells. Since this famous empress wanted enough silk produced for the use of all of the people over whom her august husband reigned, she thought of the plan of feeding and caring for silkworms. She herself carried on silkworm culture and silk spinning in order to set a

good example for the women of her empire. From the time of her reign, the cultivation of the mulberry silkworm became a common practice in China.

The cultivation of the silkworm likewise began in India at a very early date. Both of these oriental countries guarded the secret of the way the silk fiber was produced. It was not until hundreds of years after the cultivation of the silkworm had begun that other parts of the world knew where silk came from. Great caravans laden with raw and woven silk regularly left India and China for other Asiatic countries, but the source of the fiber was a mystery. The Persians bought most of the Chinese and Indian silk. They bought some of the product raw and converted it into cloth of their own design; they also sold both this and finished cloth, which they had bought ready woven, to the Greeks and Romans at tremendous profits.

When silk was first introduced into Europe, it sold for its own weight in gold. Heliogabalus, a Roman emperor from 218 to 222 A.D., was severely criticized by his subjects because of the hopeless extravagance that he displayed when he bought for himself a garment made wholly of silk. Aurelian, the Roman emperor who came to the throne in 270 A.D., is quoted as refusing to buy a silk dress for his wife in these words: "The gods forbid that I should purchase silk at the price of its weight in gold."

The Persians continued to sell silk to the Greeks and Romans until the sixth century A.D. It was during the reign of Justinian, which ended in 565 A.D., that a war with Persia put an end to this trade. Justinian, who was emperor of the Eastern Roman Empire, with a capital at Constantinople, realized that the buying of silk from the Persians was taking vast sums of gold from his realm into the realm of his enemy. He therefore passed a decree which put an end to this trade. But his countrymen were dissatisfied with this state of affairs. Consequently he paid two monks, who reported that they had

found out the origin of silk while they were in the Orient, to go to India and smuggle out some silkworm eggs. Because of climatic conditions, however, only the southern part of Europe was found suitable for this industry. Ever since that time the quantity of silk produced has always been behind the demand for it.

LEGAL LIMITATIONS ON THE USE OF SILK

Price and quantity available are not the only factors that have limited the amount of silk that people could use in times past. In England, laws were passed during the Middle Ages which forbade the use of this fiber, as well as of finery in general, to people in certain walks of life. This was apparently done for the purpose of keeping people in their proper social grooves.

Various English statutes attempting to regulate dress were enacted between 1336 and 1554. The first of these laws, passed in 1336 under Edward III, restricted the use of fur to members of the royal family, prelates, earls, barons, knights, and people of the Holy Church.

A number of laws [2] were passed during the next century restricting the use of cloth, ermine, embroideries, precious stones, silk, purple, and gold and silver ornaments. The amount of money that people of various incomes could expend upon clothing, and in some cases even the number of yards of material that people in certain stations could use, was carefully specified.

A few years later these laws were made even more rigid. Handicrafters and yeomen, together with their wives and children, were, according to this law, forbidden to wear "cloth of silk, nor silver, nor girdle, knife, button, ring, garter . . . riband, chain, nor no such things of gold nor of silver, nor no

[2] Silvia A. Miller, "Old English Laws Regulating Dress," *Journal of Home Economics*, February, 1928.

manner of apparel embroidered, aimeled [enameled] nor of silk in no way." They were further restricted in the fur they could use in their garments to lamb, cony, cat, and fox. In this same law, "carters, drivers of the plough, oxherds, cowherds, shepherds and all other keepers of beasts, threshers of corn, and all manner of people of the estate of a groom attending to husbandry and all other people that have not 40 shillings of goods" were restricted to plain woolen garments of twelve pence.

After a succession of clothing laws were tried and repealed, Henry VIII made another attempt to regulate dress in 1532 and 1533. Among other things, he decreed that women whose husbands could not afford to maintain a light horse for the king's service had no business with gowns or petticoats of silk, French hoods, or bonnets of velvet. Queen Mary further added to the statute books by fining a man whose income was under £20 a year for displaying silk on his cap or shoe, and women of the station of nursemaid for wearing silken ribbons. The last of the English laws imposing restrictions in dress was passed in the year 1554 during the reign of Philip and Mary.

These restrictions had the effect of causing increased longings for the forbidden fabrics. When they were later repealed, there remained but one limitation on the general use of silk—that of cost.

CREATIVE CHEMISTRY TO THE RESCUE

It was here that the creative chemist stepped into the picture. The longing of the human race for a certain commodity had outdistanced Mother Nature's ability to furnish this commodity. In other words, there were not enough worms in existence, or the possibility that there would ever be enough because of the fact that few places in the world had the proper temperature-humidity conditions for sericulture. This

A FORTUNE IN A SUNDAY DRESS

Four generations ago new dresses were few and far between because the vast amount of material in one garment was very costly. To-day everybody can wear beautiful clothing every day in the week. (From a fashion plate, *Godey's Ladies' Book.*)

made it impossible to supply all of the silk wanted by people in all walks of life.

The time taken by a silkworm to spin a cocoon is three to four days. During one minute it makes about six elliptical movements of the head, spinning during this time four to six inches of fiber. A total of 300,000 movements of the head are made during the entire spinning of the cocoon. The cocoons are made of an unbroken double fiber from 1,500 to 4,500 feet in length. The chemist has revolutionized the silk industry by designing equipment that exceeds the speed of the silkworm hundreds of times over.

Using raw materials which, in themselves, would be useless for making textile fabrics, science has created new fibers which have no exact counterpart in nature at all. Even the lowly cornstalk has found an important place in the modern scheme of things by the discovery that the chemist can convert it into cellulose pulp which he has made suitable for the production of rayon and other synthetic cellulose articles.

RÉAUMUR

René Réaumur, a French physicist living from 1683 to 1757, was the first person who dreamed of the possibility of making silk artificially. He published *A History of Insects* in 1754, in which he makes the following specific prophecy:

> Silk is merely a liquid gum which has been dried. Could we not make silk ourselves with gums and resins? This idea, which at first glance might appear fanciful, is more promising when closely examined. It has already been shown to be possible to make varnishes which possess the essential qualities of silk. . . . But how can we draw these varnishes into threads? We cannot, perhaps, hope to draw out the threads as fine as those obtained from silk worms, but this degree of fineness is unnecessary and it does not seem impossible either to spin them into threads, or to spin them even as fine as natural silk, when we consider to what an extent art may be carried.

COUNT CHARDONNET

Although numbers of people tried to act upon Réaumur's suggestion, none of the varnishes known at that time were found to be adaptable for making textile fibers. In 1875 Christian Friederich Schönbein, a German chemist, discovered a method of making nitrocellulose, which is now described in all of our elementary textbooks—the treatment of cellulose with a mixture of concentrated nitric and sulphuric acids. Ten years after this discovery, a French chemist—Audemars of Lausanne—actually took out patents for the production of "artificial silk" from a solution of nitrocellulose in various solvents. The fiber which this scientist made, however, was not entirely practicable at that time for the making of textiles.

It was not until 1884 that a successful artificial textile fiber was produced. The inventor was Count Hilaire de Chardonnet, a French scientist who was born in 1840 and died in 1924 and who had studied under Pasteur at the École Polytechnique in Paris. Chardonnet first became interested in silk while he was a student. His interest resulted from the fact that Pasteur was at that time engaged in a study of the diseases of the silkworm.

It had long been known that silk was produced from a gum exuded by the worm in the form of a pair of fine filaments. The filaments are covered over with a second type of secretion which cements the fibers together. The fiber itself consists of a protein to which the name of *fibroin* has been assigned but of which the exact chemical structure is not yet understood. Elementary analyses of this substance have shown that it has approximately the composition given by the empirical formula $C_{15}H_{23}N_5O_6$. The gummy sheath which cements the two fibers together is called *sericin* and is similar in composition. Analysis shows it to have the elementary composition shown by the formula $C_{15}H_{25}N_5O_8$. The sericin is removed from the

silk by a boiling-off process, the fiber itself being comparatively insoluble in boiling water, and the gum soluble.

Chardonnet's first inspiration was to try to digest the leaves of the mulberry tree—the food on which the cultivated silkworm feeds—by some chemical means, and then force the liquid through some small opening, such as a capillary tube. Reasoning from this point, he came to the conclusion that the leaf of this tree consisted essentially of cellulose and that it did not differ materially from cellulose from other sources. But it required many years to arrive at this conclusion.

Chardonnet's preliminary work dates from 1878. It includes a study of the life and habits of the silkworm, and a study of the chemical nature of the mulberry leaf and body of the tree. It took him some time to free himself from the belief that there was some peculiar characteristic of the food of the worm that made it possible for silk to be produced. In fact, the first successful fibers made by this great research worker were produced by a series of chemical treatments from the cellulose of mulberry trunks and limbs. Later he tried wood from other trees, and finally found that he could use fine white tissue paper or cotton. In fact, the last-named products served much better for his process than wood pulp.

The Chardonnet process consists briefly in *nitrating* cellulose with nitric and sulphuric acid; *dissolving* the resulting nitro-cellulose (a product similar to guncotton in composition) in an ether-alcohol mixture; *spinning* the filaments by forcing the liquid through minute orifices either into the air or into a hardening bath; denitrating, bleaching, and washing.

In Chardonnet's first memoir to the French Academy, he did not mention denitrating the fibers. As a matter of fact, the first fibers that he produced were quite inflammable, and additional work had to be done by the inventor to make the product safe for use. In 1889, five years after the first publication of his results and before he had perfected his fiber commercially, he established the first synthetic fiber plant in Besançon, his

own home town in northern France, as soon as he could interest enough people in the proposition to capitalize his venture.

Chardonnet's original plant continued to operate successfully until the opening of the World War in 1914. At that time the French Government took it over for the manufacture of gun-cotton. At the close of the war the plant was sold to the French associates of the du Pont interests. The plant is operating to-day, using the viscose process (to be discussed later) rather than that of Chardonnet.

One of the early plants to manufacture textile fibers by the nitrocellulose process was located at a place in Belgium, which was named Tubize on this account. The Tubize Artificial Silk Company of America, founded in 1920, is an outgrowth of the original concern and uses the Chardonnet process. The plant of this company is at Hopewell, Virginia.

CUPRAMMONIUM FIBERS

The second type of synthetic textile fibers to be invented was the cuprammonium filament presented for patents in 1890 by Louis Henry Despaisses, a French scientist. Because the inventor died before the final acceptance of the patent, it was not published according to the French law of that date. In 1897 H. Pauly patented practically the same process in England with but a few modifications. The process consists of digesting cellulose (usually cotton linters) in an ammoniacal solution of copper sulphate, and then forcing this liquid through the tiny orifices of a spinneret into a hardening bath of dilute acid.

In 1899 Max Fremery and John Urban took out patents for improvements on Pauly's process, which led to the establishment of the Vereinigte Glanzstoff-Fabriken at Elberfeld, Germany.

In 1901 Dr. Edmund Thiele, of Barmen, Germany, took out patents for an improved process for drawing filaments into

finer fibers by a method of "stretch spinning." His invention consisted in drawing the filaments out to the desired size before coagulation, and keeping them under tension for the short time necessary for them to harden. The firm of J. P. Bemberg A. G., of Barmen, Germany, established in 1792 and operated as a dye works and mercerizing establishment from that time on, began making synthetic fibers on an experimental scale, using the process owned by the Vereinigte Glantzstoff-Fabriken for producing the fibers, and that of Thiele for drawing them into extremely fine filaments during spinning by the stretch method. When these combined processes were fully worked out and placed on a paying basis, the Bemberg company began to devote itself exclusively to the manufacture of synthetic textile fibers.

The American Bemberg Corporation, an offshoot of the German concern, was established in 1925. The works are located between Johnson City and Elizabethton, Tennessee.

A modification of the cuprammonium process was worked out by Dr. Emile Brennert, of Strousburg, Alsace, in which the raw material is dissolved in ammoniacal copper carbonate. This process is being used in this country to a limited extent.

VISCOSE

Only two years after Despaisses' first announcement of cuprammonium filaments, two English inventors—Charles Frederick Cross and Edward John Bevan—discovered an entirely new method of digesting cellulose. The product developed by these men was produced in two stages: (1) the digestion of the cellulose by sodium hydroxide, and (2) the conversion of the alkali-cellulose thus formed into a soluble xanthate by treatment with carbon disulphide. A brown, viscous liquid is produced as a result of this treatment, which the inventors named *viscose*. Hence the name of the process.

It was three years after Cross and Bevan had worked out

the viscose method of dissolving cellulose before a serious study of the spinning capabilities of the liquid was undertaken. This research was done at the Incandescent Lamp Works at Zürich, Switzerland, with the idea of applying viscose filaments to the manufacture of incandescent gas mantles. A measure of success attended this first venture, but it was found impossible to produce continuous threads of the quality and quantity necessary to market the product as a yarn.

THE TOPHAM BOX

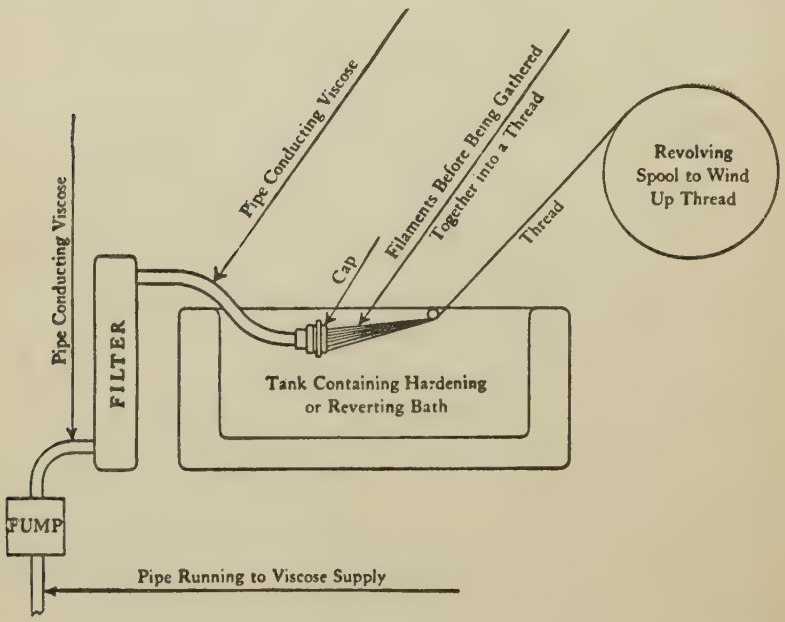
It was not until 1900 that the first exhibition of viscose rayon goods took place. It was almost ten years after this date before the major technical difficulties of the process were solved. The spinning and twisting of the individual threads was the part of the process that gave the most difficulty. This part of the problem was solved by an English inventor named Charles Topham, who devised a centrifugal box for drawing the fibers forward out of the coagulating bath, twisting them into a thread, and winding the threads into a veritable cocoon of mammoth proportions.

When the fibers harden in this tightly wound condition, they form what is called the cake. The yarn can be unwound from this with little difficulty.

After the viscose process was finally perfected through patient and continuous research participated in by a number of agencies, it outdistanced all other processes in quantity production. The reasons for this are fourfold: (1) well organized research; (2) strong financial backing (the inventors secured the backing of Samuel Courtauld & Co., Ltd., silk manufacturers of England); (3) the invention of the Topham box, which solved the spinning difficulties and made quantity production possible; (4) the discovery that either wood pulp or cotton linters would serve as a satisfactory raw material.

The rights and patents of the viscose process were sold to

many concerns in various parts of the world. The Viscose Company, established in the United States in 1911, was the first company to manufacture rayon in this country by any process. The company has plants at Marcus Hook, Pennsylvania (said to be the largest rayon plant in the world), at



A DIAGRAM OF THE METHOD OF MAKING RAYON

Lewistown, Pennsylvania, Roanoke, Virginia, and Parkersburg, West Virginia. It has a plant at Nitro, West Virginia, which produces cellulose boards from cotton linters and ships them to some of the other rayon plants as a raw material.

The Du Pont Rayon Company is the second largest producer of viscose rayon in this country. It operates under patents secured through a merger with Comptoir des Textiles Artificiels, Paris, which owned the right to use this process. The works of the Du Pont Rayon Company are at Buffalo, New York, and Old Hickory, Tennessee.

There are quite a number of other plants in this country manufacturing rayon by the viscose process.

FROM DOPE TO DRESSES

The fourth type of cellulose textile fibers—those from cellulose acetate—were first worked upon by Cross and Bevan, the inventors of viscose. A refined modification of this pioneer process was applied at the close of the World War to the manufacture of a product called celanese.

Soon after Cross' and Bevan's first work with cellulose acetate fibers in 1892, they dropped the process because of technical difficulties involved. Workers in the United States and Germany spent some time in improving the process, but it was never advanced to the commercial stage.

At the close of the World War, the extensive "dope" plant located at Spondon, England, found itself with equipment for making airplane wing dope, but with no demand for the product. The method used by this plant (the British Cellulose and Chemical Manufacturing Company) for making cellulose acetate dope was based on processes worked out under the pressure of war-time needs. The inventor, H. Dreyfuss, a Frenchman, was responsible for this process, which consisted of producing acetone-soluble cellulose acetate.

After surveying the field carefully, the owners of the plant decided that the best outlet for using Dreyfuss cellulose acetate dope was in the making of textile fibers. After overcoming many technical and financial difficulties, they placed *celanese* on the market.

The Celanese Corporation of America, with a plant at Amcelle, Cumberland, Maryland, is a branch of the English company. There are other more recent plants in the world manufacturing synthetic fibers by the use of various modifications of the cellulose acetate method, but they do not, as yet, produce any significant quantity of yarn.

One of the chief virtues of cellulose acetate fibers is the fact that they resist water. This resistance to water makes them difficult to dye, but this problem has been met by the chemist, and capitalized. Dyes that are applicable to viscose rayon, for example, will not color cellulose acetate, and vice versa. This makes it easy to weave a special pattern with two fibers, which, to all outward appearances look alike, and then dye them in one bath with a resulting beautiful two-color effect.

CORNSTALKS AND CANE

A few years ago attention began to be drawn to the advisability of finding out how to utilize farm wastes as a means of helping to improve the status of agriculture in this country. Congress appropriated $50,000 for research in this field, and designated the Bureau of Standards as the agency for carrying out this program. Dr. Warren E. Emley, chief of the organic and fibrous materials division of the Bureau, entered into a cooperative agreement with Iowa State College, at Ames, whereby the chemical engineering laboratory at that college, under the direction of Professor O. R. Sweeney, should conduct a piece of research on the utilization of cornstalks.

The first work done at Ames has been the production of an insulating and building board from the cellulose fibers of cornstalks. The suitability of cornstalk cellulose for making textile fibers was also investigated.

Sugar cane, and any other source of cellulose, is a potential raw material for making textile fibers synthetically.

HOT DOGS AND HATS

The production of synthetic clothing has not been restricted to the human race. Hot dogs, once trimly clad in shirts made of intestines, are now more conveniently dressed in tight-fitting jackets of Visking, a synthetic cellulose product. A

recent practice in this connection is to encase sausage and "weenies" in Visking coverings and then remove the casings and send them forth entirely unclad. They have been found to hold their shape well in this condition.

Cellophane, a viscose cellulose product made up to the very last stages in a manner identical to that used with viscose rayon, is also finding widespread applications for wrapping candy boxes, powder puffs, food products, children's toys, and a host of other products sold over the counter. The new Cellophane produced by du Pont is waterproof, dustproof, and fumeproof and can be dyed any color and brocaded in any design. It can even be twisted into strands and knitted into ladies' sport hats.

SYNTHETIC WOOL

At least two synthetic wool products are on the market. One of these is made from a flax base, the other from waste rayon. Both of these fibers depend for their warmth upon the fact that they are given a chemical treatment which makes them crinkly, and therefore capable of entrapping air. This makes for good insulation, but the product is not as good as wool in that respect.

DYES AND DISPOSITIONS

The woman of to-day, be she young or old, can reflect her own individuality in the color of her costume. The man can express himself as colorfully as he chooses in his ties, suspenders, and socks. There are now no restrictions as to the color one may wear, except those of his own disposition.

This was not always true. Although the dyeing industry is one of venerable antiquity, it has been only within the last half or three-quarters of a century that color in costume was capable of a wide range of choice by everybody in general.

THE HISTORY OF DYES

The earliest historical records of almost all races of people give fragmentary references to the use of dyes of various sorts. The question as to the nature of the instinct which first prompted members of the human race to desire colored fabrics is one that can be answered only by conjecture. The origin of the word *color* is of interest in this connection. The Reverend Walter W. Skeat, an eminent authority on the subject of etymology, states that it was derived originally from one of two Latin verbs, *celare* or *occulare,* both of which mean to hide, cover, or conceal. Whether this interpretation indicates that the staining of the body as practiced by various primitive races of people may have given rise to the term *color,* or whether the original meaning had reference to the application of coloring matter to a fabric for the purpose of hiding, covering, or concealing the natural drab appearance of most raw fibers, cannot be answered accurately from the insufficient historical evidence at hand.

An interesting scrap of historical incident showing the practice of staining the body with a dye is given by Julius Cæsar in his description of the inhabitants of Britain at the time of his second invasion of the islands in 54 B.C. In his *Commentaries,* Cæsar describes the inhabitants of Kent, the maritime region in which he first landed, as differing but slightly in dress and customs from their Gallic neighbors across the channel. The inhabitants further inland, however, he describes as possessing a much more primitive type of civilization: "Most of the inhabitants of the interior do not sow corn, but live upon milk and flesh and are clad in skins. All Britons in fact dye themselves with woad, which produces a blue color, and they are therefore more horrible in appearance in battle."

Of course all of us are familiar with the fact that the American Indian daubed himself with color before engaging in a military venture.

The reasons why people first began to dye their garments will never be known, for written records were not kept at the time the practice of dyeing originated. Some philosophers believe that a desire to beautify one's clothing in order to appear well-dressed before members of the opposite sex had something to do with the origin of the practice. Others think that human beings were prompted to dye their clothes because of their admiration for the colored ornamentation displayed on all sides by nature.

Herbert Spencer advanced the so-called Rank Theory, in which he attributed the origin of dyeing and of the use of fancy and distinctive costumes to a desire on the part of the human race to indicate its rank. Thus in the early days when the skins of animals were the chief raw materials for making clothing, the chiefs of the various prehistoric tribes were the ones with the greatest leisure, and consequently killed most game and secured the finest skins. The lowlier members of the tribe had little or no time for hunting, and hence they could not compete with their superiors in the matter of dress. In a somewhat similar way, expensive dyes could not be afforded by any but the most wealthy, and color came to be an indication of rank. At various times, also, certain beautiful colors have been restricted to royalty and to the church by law, thus placing restrictions other than expense on their use.

DYES FROM NATURE

It may be that none of those who have speculated on the reasons why man first began to dye his garments is correct. However he came to do it, it is a fact that he first turned to nature for dyes that were suitable for his purposes.

Mother Nature was very stingy with man in this respect. For, from the beginning of time until about the middle of the nineteenth century he had found but a bare half-dozen dyes of sufficient importance to feature as articles of trade. Berry

juices, all sorts of weeds, flowers, onion skins, the barks of trees, the roots of plants, the liquors from fermenting wood, bugs, minerals of various kinds have all been tried with varying degrees of success. Those which have reached a degree of commercial importance are indigo, madder, Tyrian purple, cochineal, logwood, and fustic. A very few others have had their day, but the vast numbers of the natural dyes have been used only in the home, their use handed down from father to son as great family secrets.

Indigo, one of the oldest dyes of which there exists any historical record, is obtained by the fermentative steeping of the stems and foliage of several species of shrubs belonging to the Indigofera family. The juices obtained from these plants are colorless when out of contact with air, but become blue by exposure to air. Fabrics dipped into the colorless juices become dyed with a permanent blue when they are subsequently exposed to air.

Pliny mentions this dye (Indicum) and describes it as being of vegetable origin. As to its exact source and its method of preparation for the market, however, this historian is not absolutely accurate, probably because of the fact that it was of decided advantage to those engaged in the production of the dye to surround its origin with the greatest possible amount of secrecy.

Mummy draperies 4,000 years old which are believed to have been dyed with indigo are now in existence. With the introduction of synthetic indigo, the production of the natural product began to decline. In 1897 nearly a million acres of land in India were devoted to the cultivation of the indigo plant; the annual crop from this vast area was valued at something over $20,000,000.

Madder is a dye consisting of the ground cortex of the root of the madder plant (*Rubia tinctoria*). When this dye is fermentatively steeped in water it produces a bright red coloring matter. In very ancient times this dye was used by the

natives of India, Persia, and Egypt. Herodotus describes the outer garment of the women of Libya, a nomadic African tribe, as being made of hairless tasseled goat-skins colored with madder. Many ancient Latin writers refer to this bright red dye as *rubia*.

For centuries the production of madder constituted one of the chief industries of Asia Minor and India. As recently as sixty years ago, 50,000 acres in France alone were given over to the cultivation of this plant.

Tyrian purple, the finest and most costly of the dyes of the ancients, was first discovered by the Phœnicians. It was obtained from two species of Mediterranean shellfish, namely the *Murex trunculus*, and the *Murex brandaris*. It is secreted by these animals in a small sac in the throat (if such animals could be said to have a throat), and is used by the animal to color the water and hide its escape when attacked. The amount of dye secreted by each animal is so small that it requires about twelve thousand of the shellfish to produce three grains of the dye. Hence its high price.

The name Tyrian purple was given to this dye because of the fact that in ancient times it was sold by the inhabitants of the rich Phœnician city of Tyre. The wealth of Tyre is said to have been derived quite largely from the sale of this very costly dye. So costly was Tyrian purple that only kings could afford it. It thus comes to be the badge of royalty, and the Latin term *purpureo genitus* was synonymous with the expression "of royal birth."

There is historical evidence to show that Tyrian purple was discovered about 1500 B.C.

Kermes, a crimson dye, was obtained in olden times from the dried insects (*Coccus ilicis*) which frequent the boughs of a species of the oak tree. The insects of this species lay their eggs in groups on the boughs of the tree. These become covered with a sort of down, so that they appear to be excrescences from the limb itself. The dye is procured from the

female of the species, which, when alive, is about the size of a cherry seed. When dead this creature shrivels up until it is about the size of a grain of wheat.

This dye was known to the Phœnicians before the time of Moses. It was also known to the Greeks and Arabians. The term *crimson* is derived from the Arabian name of the insect, *kermes*. The crimson frequently spoken of in the Old Testament is supposed to refer to the color derived from this source. This dye was found to be in general use in Europe during the tenth century.

Cochineal, a more recent dye of bug origin, was derived from the dried bodies of the females of *Coccus cacti*, and was found to be in use by the inhabitants of Mexico at the time of the discovery of America. The insects are much smaller than those from which kermes is derived. Cochineal, like kermes, produces brilliant reds. This dye was introduced into Europe in 1550.

Logwood is the most important of dyes that at various times have been derived from wood. Logwood is a concentrated extract made from chips of the heart wood of a large and rapidly growing tree called by the formidable Latin name *hæmatoxylon campechianum*, or campeachy for short.

This dye, if properly applied to fabrics, can be made to give a series of colors—purple, gray, black. With the shortage of German dyes suffered by this country at the opening of the war, quantities of logwood were rushed into the American market. This dye, in the hands of mill-men who were not accustomed to its use, faded and proved generally unsatisfactory. This was the chief reason why the American dye chemist received such a black eye at that time. But little did the public know that it was one of nature's own dye products causing most of the trouble. Without bothering to find out much about the sources of the difficulty, people shouted loudly for "natural dyes," preferably for the "good, old-fashioned vegetable dyes."

ARTIFICIAL DYES

It is a matter of history that the natural dyes have always been exceedingly expensive. It was for the purpose of lowering the cost of producing dyes and thus making them cheap enough to be within the reach of all that the chemist conceived the idea of attempting to prepare dye materials by synthetic means. With this end in view, various lines of research were undertaken during the early part of the nineteenth century.

The first problem in preparing a synthetic substitute for a natural product is to find out the chemical structure of the material in question. The next step is to find out how to prepare an artificial product having the composition of the analyzed substance.

Indigo was the first dye to be subjected to the chemist's scrutiny. This, however, proved to be a hard nut to crack, and many years were required to analyze and duplicate the compound.

Perkin's mauve.—While the foremost chemists of the day were hunting for means of duplicating natural dyes in the laboratory, William Henry Perkin, an English lad eighteen years of age, accidentally prepared the first artificial dye in 1856. Perkin was a student at the Royal College of Chemistry in London, studying under Hofmann. It was his ambition to prepare quinine synthetically. Each time he completed a set of experiments and expected to obtain white crystals of the drug he wanted to make, only failure greeted him. One day, when pouring a thick, dark-colored, uninteresting-looking solution down the sink, he found that when the substance was diluted with water it had the properties of a dye.

Perkin hastened to take advantage of his find and to investigate the structure of the new material. He found that he could repeat the process as often as he wished, so he placed the substance on the market. He called the new dye, which was a pleasing shade of subdued purple, mauve. He first tried

to sell it to the English textile manufacturers, but they were too conservative to buy anything produced in so unusual a manner. He then took the product to France where the French manufacturers of cloth bought it. Much of the cloth that they dyed with the new product was returned to England where it enjoyed quite a vogue with the English women. So popular did it become, in fact, that *Punch* referred to the situation by saying that the women were suffering from an epidemic of "mauve measles."

The success of Perkin stimulated other chemists to renewed efforts in the matter of analyzing natural dyes and preparing artificial dyes synthetically. The problem of analyzing the commercially important dyes and of finding out how to produce the identical compound in the laboratory proved to be so baffling that some of them required many years to fathom. But every single one of them has been made in purer form than nature can make them. Even the "purple of kings" has been made quite cheaply, but is now used scarcely at all because other synthetic purples have proved to be more beautiful.

Meanwhile, numbers of artificial dyes which have no counterpart in nature at all have been produced. The number has swelled to the hundreds and thousands so that at the present time dyes are cheap enough to afford beautifully colored fabrics for every one who wants them. The commercial production of most of the natural dyes has dwindled to almost nothing at all.

Colors from coal tar.—The success of synthetic dyes would never have been possible had it not been for the fact that cheap raw materials were found in the products derived from the distillation of coal tar.

CARING FOR OUR CLOTHING

The modern chemist has learned not only how to spin gorgeous textile fibers from solutions that he has experimented

with in test tubes, but how to maintain fabrics and cause them to give the maximum of service. He has studied all fibers carefully, be they man-made or natural, and has found out their response to various cleansing agents. As a result, everything from gloves, hats, shoes, dresses, suits, and fur coats, to window curtains, rugs, overstuffed furniture, and the interior of an automobile can now be refreshed and made as clean as new.

THE RIVER FOR A WASH BASIN

In olden times the family clothing was washed in the nearest stream of water, without the use of any soaps whatever. Soap was not known until comparatively recent times. A pounding action, achieved sometimes by the use of the bare feet, served to float some of the dirt out of the fabrics. In some remote parts of the world, even to this day, the family washing is done in a stream of flowing water, sometimes with the assistance of a crude wooden wash board. Even in the time of our grandparents it was a common practice to wash clothing in a galvanized tub, with water heated on top of the stove, and with soap made at home from lye and meat scraps.

A BRIEF HISTORY OF SOAP

Soap as we know it to-day is the product of the last three-quarters of a century. There are several references in the Bible to material which the old English translators have called "sope," but none of these could have referred to the modern product or anything related to it. Thus in Jeremiah 2:22 we read: "For though thou wash thee with nitre and take much sope, yet thine iniquity is marked before me."

And in Malachi 3:2 the following is to be found: ". . . for he is like a refiner's fire, and like fuller's sope."

In the first of these references, the commentators tell us that the word which has been translated as *sope* in the original

Hebrew version of the Bible is *borith*, which they have reason to believe was used to refer to wood-ash alkali. Although the ancients did not know it, the ash left after wood is burned consists essentially of sodium and potassium carbonates. They found out by accident that the liquor obtained by leeching wood ashes in water had a detersive or dirt-chasing action, and they made the most of their find.

In the second reference quoted above, *fuller's sope* unquestionably refers to fuller's earth, a clay of a special texture used as a grease absorbent by wool spinners and weavers of ancient times.

In the writings of Pliny the Elder, in the first century A.D., a description is given of the preparation of a crude soap from goat's tallow and beech-wood ash. This is one of the first historical references to the making of a detergent by the action of an alkali upon a fat.

Pliny describes one of the earliest uses of the soap as a hair pomade. Later it came to be used for laundering fine linen and laces. It did not come into general use for laundry and toilet purposes until about the eighteenth or nineteenth century.

In the early history of our own country, the extraction of lye from wood ashes and the boiling of this alkali with the fat remnants from the kitchen was a common household task. The first step toward removing soap-making from the home was made by the early soap- and candle-maker, who went from house to house collecting fat scraps which he rendered in an open kettle. The tallow derived from this operation he used in making soap and candles, which he offered for sale.

SOAP AND THE ALKALI INDUSTRY

The manufacture of soap on a large scale, however, was impossible so long as the supply of alkali was limited to wood ashes. In 1791 Nicolas Le Blanc, a French chemist, made

available a cheaper and more extensive supply of sodium carbonate by introducing a method of making soda from common salt. The introduction of the Le Blanc process and, a few years later, of the Solvay (soda-ammonia) and the electrolytic processes solved the alkali problem and made possible the extension of wholesale soap manufacturing. Some manufacturers at the present time causticize their own carbonate by a process similar to that mentioned above; others buy the sodium or potassium hydroxide ready for use.

SOAP AND THE FAT INDUSTRY

Until the work of the French chemist, Michel Eugène Chevreul, however, soap manufacturing was done more or less by rule of thumb. This chemist carried out extensive researches between the years 1811 and 1823, and discovered for the first time the exact chemical structures of fats and soaps. Many of the natural fats such as stearin and olein were analyzed and named by him. After these classic researches were published, it was possible to make soap by adding definite quantities of reagents according to actual combining proportions, rather than by the hit-or-miss methods formerly employed.

The growth of the alkali industry and the researches of Chevreul stimulated the soap industry, but still soap-making was limited for want of fat. The establishment of large soap factories called for a larger supply of fat concentrated in one place than was needed to keep the soap- and candle-maker busy. Fortunately the meat-packing industry was just coming into existence about this time, and it helped to solve the problem. The introduction of the process of the hydrogenation of fats likewise added to the world's supply of available fats and released considerable quantities of the commodity to the soap industry that otherwise would have been needed for food.

THE POWER LAUNDRY

The development of the power laundry is of still more recent origin than that of soap manufacture. George Johnson, a research fellow of the Laundry Owners' National Association, gives the following brief outline of the history of the power laundry in his book on *Textile Fabrics:*

During the nineteenth century laundering was first developed as an industry. In 1832 cholera broke out in London. After a time it was noted that the scourge had its greatest mortality in the dirtiest sections of the city and that cleanliness was required to combat the disease. One laundering establishment was opened at once, and in 1842 a more business-like plant was started in Liverpool, followed by two others in London. In 1846 Parliament passed an act authorizing the establishment of laundries from the public funds.

In America, the laundry industry was originated about 1827 with the invention of the detachable collar. Nine years later, Independence Stark, a manufacturer of Troy, N. Y., established a laundry to take care of the product of his own factory and of near-by collar makers. As far as records show, the first American laundry, as one thinks of laundries to-day, came into existence in 1851 as the Contra Costa Laundry at Oakland, California. It was started for the purpose of washing the clothing of the men who were attracted to the West by the gold rush. The walls of the building in which the first laundry of record was operated may still be seen, having been permitted to stand when the plant was enlarged some years ago.

The first washing machines were made of half-barrels, in which the soiled clothing was placed and washed by means of agitation. The agitator was a crude affair made of wagon-wheel spokes. Although it is not stated in the history of the first laundry, it is presumed that the power applied to the agitators was that of brawny, masculine arms. The water was squeezed from the clothes by a crude home-made wringer, the drying process being that of the old-fashioned clothes line.

In 1858 an inventor conceived the idea of washing clothes by machinery, and in the following year the first rotary washing-machine was made by Hamilton E. Smith at Pittsburgh, Pa. The inventor soon discovered that his machine did not operate efficiently, and it was not until 1862 that he obtained a patent. During the

next year he secured patent protection on the first self-reversible motion attachment to the machine. The first steam laundry in the true sense of the word was fitted up for operation in 1863 at Pittsburgh at the St. Charles and Monongahela House. From 1858 to 1873 this same inventor (Smith) experimented with an ironing machine, as a result of which the present-day flatwork ironer has been developed.

For a number of years after the establishment of power laundries, laundry service was confined to the renovating of men's garments,

Courtesy of the "Scientific American."

INTERIOR OF A LARGE MODERN LAUNDRY

This scene shows the rinsing and ironing operations.

starched pieces, and hotel and restaurant linen. It was not until about 30 years ago that family washings first found their way into the public laundry. It has been stated that the first families to patronize the public laundry were located in the mill districts of New England. This patronage was due to the fact that textile mills drew so heavily upon the supply of female labor that it was impossible to find washwomen to come into the homes to do the weekly washing. The solution of the New England housewives' problem of handling the washing, namely, the sending of soiled pieces to the laundry, has gradually spread all over the country, until in the last five years the laundry business has become more than a half-billion dollar enterprise.

Although thirty years ago power laundries were doing practically no family work, at present about 15 per cent of the families of the

country are patronizing commercial plants. This increase in business is an indication that the nation's home managers will soon handle their wash-day burdens largely as they are handling their spinning and baking problems; the work will be done away from the home.

MAINTAINING FINE FABRICS

It was a sad event indeed when a lady of ancient or medieval times soiled her best silken garment. The best that could be done under the circumstances was to take out as much of the stain as possible with water and allow the rest to stay in. Water had a detrimental effect on many of the fine fabrics, but it was the only cleansing solvent known.

In the late seventeen hundreds a deliberate search was made for solvents suitable for cleaning ladies' court dresses without damage to them. In 1825 Michael Faraday first discovered benzene, a product well known to-day in the dye and other chemical industries. A short time after this, Jolly Belin, a Frenchman, discovered that benzene would remove grease from textile fabrics.

THE FIRST DRY-CLEANING SOLVENT

This discovery marked the beginning of the dry-cleaning industry. Belin kept his discovery secret and passed his business down to his son-in-law, who established the firm of Petit Didier in Saint Denis, near Paris. Gradually the secret of the process leaked out, and other plants were founded in Austria and Germany.

After the discovery of methods of making synthetic dyes from benzene and its derivatives, this compound came to be in such great demand that it was no longer economical as the chief solvent in the dry-cleaning industry. Up until about 1869, therefore, camphene (another organic solvent) was the chief dry cleaning reagent used. Camphene presented two chief difficulties. In the first place it was highly explosive, and

in the second it was necessary to rip the garment almost entirely apart in order to use the cleaner properly.

PETROLEUM AND DRY CLEANING

It was not until some time after the Civil War that it was found that some of the volatile products derived from petro-

SCENE IN A MODERN DRY-CLEANING PLANT

In the class in spotting and finishing, the students learn to remove stains not removed in dry cleaning and to reshape a garment properly.

leum could be used in the cleansing of fabrics. The first oil had been struck on August 29, 1859, and the first well dug shortly thereafter at Titusville, Pennsylvania. But it required a number of years before the distillation of crude petroleum was developed very fully.

Even with the advent of gasoline and other volatile solvents derived from petroleum, the dry-cleaning industry was not in a position to make much progress until the development of suitable dry-cleaning machinery and of soaps that are soluble

in dry-cleaning solvents. By 1900 garment-cleaning machines, hydroextractors, solvent purification systems, and suitable soaps had come on the market.

THE MODERN DRY-CLEANING PROCESS

According to the standard practice adopted by the National Association of Dyers and Cleaners as a result of extensive research on the subject, the fabric being handled goes through carefully worked out steps after the garments are sorted as to kind and color. The process is as follows:

The fabric is placed in a metal washer. Silks and delicate materials are placed in meshwork bags to prevent damage from abrasion. The articles are first agitated for ten minutes in clear solvent, and then suitable soaps are added. A mixture of soaps, some of which assist in removing greases and others of which take out water-borne stains, are used.

A final rinse by means of a continuous flow system is given until the solvent is clear.

The garment is then relieved of excess solvent by a centrifugal process and is dried in warm air.

It is then carefully "spotted" by hand and pressed by special irons. The spotting process consists of removing by special hand methods all refractory spots which have persisted during the dry-cleaning process.

By carefully studying each article that comes to his plant, the modern cleaner can refresh everything of a fabric nature from a toy dog to a fur coat, or a sofa pillow to the rotunda rug of the world's largest motion picture house.

CHAPTER XI

RAINY DAY APPAREL

Across the window-pane
It pours and pours;
And swift and wide,
With a muddy tide,
Like a river down the gutter roars
The rain. . . .

—LONGFELLOW

A RAINSTORM seriously interferes with baseball-playing, hay-making, and plowing, but with these exceptions it has little effect upon our usual occupations nowadays. When the rain pours down, we put on our overshoes, raincoats, and storm hats and go about our business without a great deal of concern about the weather. Before 1800, however, rain was a serious matter, because rubber had not then been added to the list of man's important everyday materials.

As a matter of fact, rubber was known long before 1800, but it was put to no important uses in civilized parts of the world. Columbus, during one of his four trips to the New World, found some Indian children in Haiti playing with balls made of a new gum-like substance. These balls attracted his attention because they bounced so readily. They interested him so greatly that he took some of them back to Spain with him. The Spaniards, however, were concerned first and last with gold and precious stones. They were so keenly disappointed that Columbus had failed to bring back large quantities of treasure that they paid little attention to anything else in his cargo. Consequently they did not trouble to find out whether the elastic balls might be of any importance or not.

THE FIRST GUM SHOES

Almost a century after Columbus' time a group of missionaries to South America found the natives using this same kind of gum to make crude waterproof shoes. The natives prepared the gum by smoking a liquid that they secured by cutting gashes in the bark of a certain kind of tree. This tree they called *cahuchu,* meaning "weeping wood." From this word comes the English word *caoutchouc,* which is sometimes applied to rubber. The missionaries followed the example of the natives and used this gum to make crude shoes and raincoats.

A HISTORICAL RUBBER

A few articles made of caoutchouc gradually found their way into Europe. Joseph Priestley discovered in 1770 that this material would rub out pencil marks, and for this reason he named it *rubber.* It soon came to be called India rubber because it was imported at that time from the West Indies. Not long after this, an English firm began to manufacture rubber erasers, which were eagerly bought by draftsmen and artists at seventy-five cents each.

The first pair of rubber shoes seen in the United States was shipped from South America in 1820. For several years these were looked upon merely as a curiosity. Three years after the first pair came, however, five hundred pairs were imported. They sold quite easily at sixteen dollars a pair, a price that would be enormous even to-day. Other consignments of shoes were imported and were sold at once.

MACKINTOSHES

In the meantime, Charles Mackintosh, an inventor of Glasgow, had come upon the idea of using rubber for making waterproof clothing. In those days travel in Scotland was largely by way of the stagecoach. The stagecoach passengers were

often so numerous that some of them were obliged to ride on top. When the weather was wet, as was frequently the case, these unfortunate persons were thoroughly drenched. Because of these conditions, Mackintosh saw the business possibilities of clothing that would shed water. He discovered that rubber would dissolve in naphtha, a liquid distilled from petroleum. When a solution of rubber in naphtha was spread on a piece of cloth, he found that the naphtha evaporated and left the rubber in a thin film on the cloth.

Mackintosh took out patents in 1832 on this method of rubberizing cloth. Soon after this he started a factory in Manchester, the textile center of England, and began to manufacture raincoats from his rubberized cloth. The first of these raincoats gave most unsatisfactory results, because the rubber film on the under side of the cloth became very sticky when it was warm, causing much damage to the clothing and the patience of the wearers. Mackintosh thereupon thought of the plan of placing a second piece of cloth on the rubber film, thus having two layers of cloth with a layer of rubber sandwiched in between. These improved "mackintoshes" were much better than the first kind, but they also had some faults.

At the same time that Mackintosh was beginning the manufacture of rubberized coats, people with a business turn of mind in America were having a rubber shoe fever. Because raw rubber was so cheap and rubber shoes brought such high prices, the belief became common that enormous profits could be made in the manufacture of shoes and other articles of rubber. Rubber companies sprang up like mushrooms. The Roxbury India Rubber Company, with headquarters at New York City, was one of the most important of these new companies.

CHARLES GOODYEAR

Charles Goodyear, a partner of his father in a Philadelphia hardware business, while on a business visit to New York

Photograph by Ewing Galloway

TAPPING THE RUBBER TREE

City in 1833 chanced to pass the retail store of the newly established Roxbury India Rubber Company. Goodyear had heard about this company, which had started with a flourish with a capital of $300,000, and he stopped to look at the display of rubber goods in the window. He was particularly attracted by a newly invented life-preserver and he went into the store and purchased one of these articles so that he could examine it very carefully at his leisure. While he was in the store, he engaged the clerk in conversation on the subject of rubber and learned a great deal about this interesting material.

After Goodyear returned to Philadelphia, he examined his new life-preserver at odd times and figured out a new and better method of inflating it. When his father's business failed a few months later, and he became heavily involved in debt, he decided to go to New York and try to sell his improved life-preserver. When he arrived in the city, however, he found all of the rubber merchants and manufacturers in dire distress. Rubber goods had proved to be a great disappointment to every one because they were unable to stand changes of temperature. In winter, with the temperature below freezing, rubber overshoes became hard as stone and very brittle; in summer, with the thermometer at one hundred degrees on a sultry day, they became a sticky mass of gum.

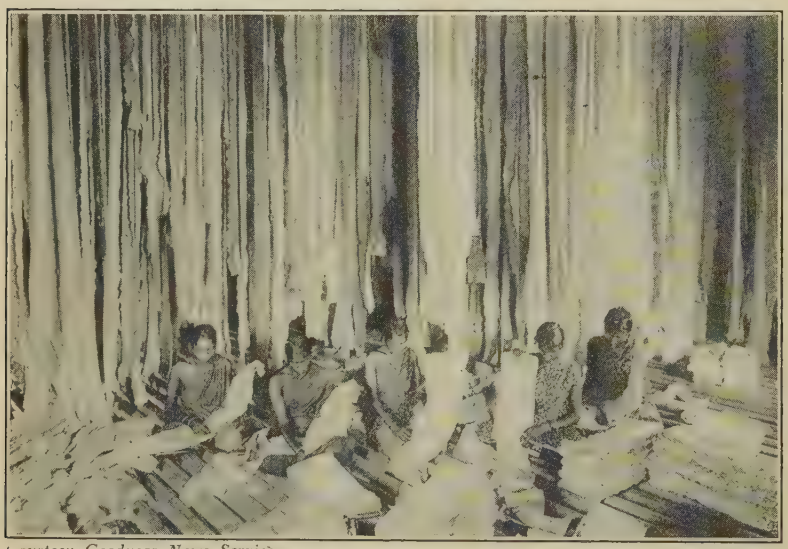
American companies were not the only ones to have their troubles with rubber. Word was received that Mackintosh's raincoats likewise were unsatisfactory because the rubber cracked and became leaky during the cold rainstorms of winter.

Charles Goodyear believed, however, that rubber could be treated in some way to remedy its defects. Accordingly he purchased a few pounds of rubber and set to work to find a method of making it fit for use. For a long time he worked day and night. He melted the rubber, pounded it, kneaded it, poured chemicals upon it, and treated it in every imaginable way—but to no avail.

Although he found that it was not going to be the quick and

easy matter that he had at first thought to make rubber fit for use, Goodyear did not give up his undertaking. The Roxbury India Rubber Company went bankrupt; other rubber companies failed, and people generally lost interest in rubber; but he continued at his work.

During those years of hard and unrewarded labor, Goodyear tried mixing crude rubber with alcohol, chalk, turpentine,



Courtesy Goodyear News Service.

PREPARING CRUDE RUBBER FOR SHIPPING

After the latex has been precipitated by acids, the rubber is washed, hung up to dry, and packed.

and almost every chemical that he could lay his hands upon. In addition to his work with crude rubber, he purchased a barrel of sap just as it comes from the tree and began to experiment with that. An Irishman in his employ is said to have greeted him one morning with the news that he had found out the great secret. This man had dipped a pair of trousers into the barrel of the sap, and he was wearing them with great pride. Indeed they were covered with a thin layer of rubber

which dried so smoothly that they looked as if they had been varnished. Goodyear thought that perhaps the secret really had been stumbled upon, but the further events of the morning showed that this was not true. When the man sat down to work and attempted later to rise, he found that he was stuck fast, with both legs firmly cemented together. It was with considerable difficulty that the sticky garment was removed from the unfortunate experimenter.

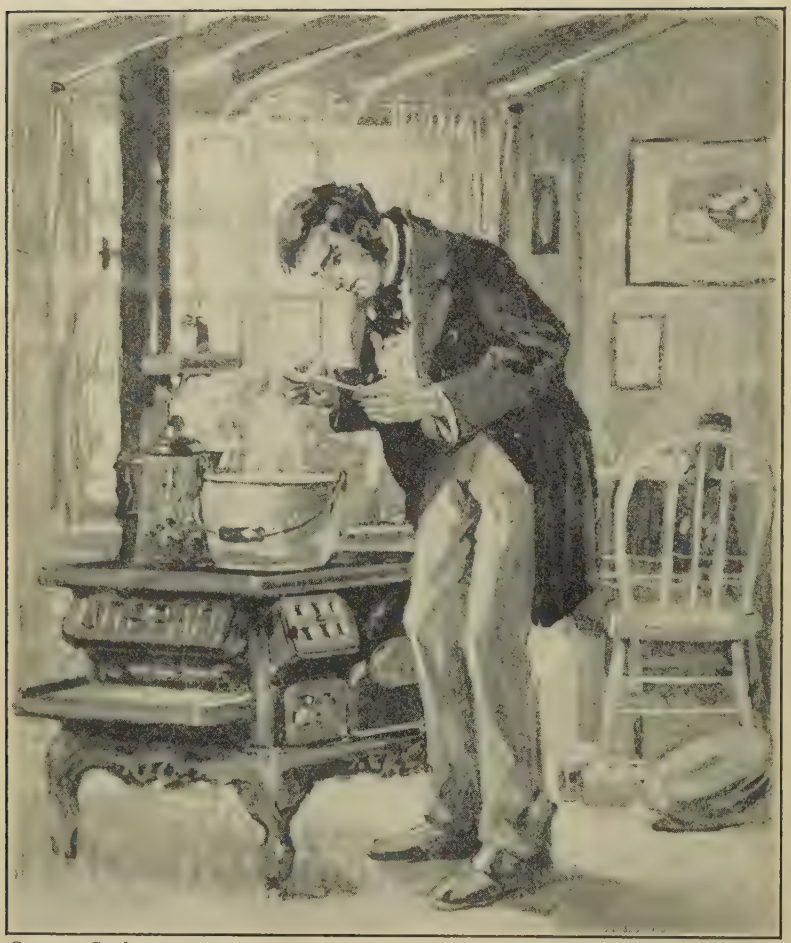
Goodyear found in 1836 that rubber could be hardened by treating it with nitric acid. Thereupon he secured a contract from the United States Government for making a large number of rubberized mail bags. Before this contract was filled, however, it was found that rubber treated with nitric acid was not able to withstand hot weather.

In spite of this serious discouragement, Goodyear continued to struggle on for several more years. He borrowed money from his friends until he no longer had friends to borrow from. His wife and children suffered actual want. He was put into jail more than once for debt. He clung to the idea, however, that rubber could be made a valuable material if the secret of making it impervious to the seasons could be found.

During these years of struggle Goodyear is said to have dressed in rubber clothing in order to test out the durability of his products. He was once described thus: "If you see a man with a rubber coat on, rubber shoes, rubber cap, and in his pocket a rubber purse with not a cent in it—that man is Charles Goodyear."

VULCANIZATION

It was not until 1844 that Goodyear had the fortunate accident that showed him how to make rubber fit for use. A fellow inventor by the name of Hayward had conceived the idea of mixing rubber with sulphur, but had not been able to make a satisfactory product. Hayward was discouraged and ready



Courtesy Goodyear News Service

AN ARTIST'S CONCEPTION OF THE DISCOVERY OF VULCANIZATION BY CHARLES GOODYEAR

to quit his experiments, and Goodyear therefore purchased all rights to the use of rubber and sulphur mixtures. One of the tests Goodyear made was to dissolve a mixture of rubber and sulphur in turpentine, and coat strips of cloth with it. One day he hung a number of these strips near a stove in order to

evaporate the turpentine. One of the samples accidentally fell upon the stove. Goodyear was about to throw away the black mass that resulted, when he noticed its peculiar appearance. After making further tests, he found that a mixture of rubber and sulphur baked in a moderate oven had all the qualities he had been seeking. This process proved to be the one that changed rubber from a useless failure to one of man's most valuable kinds of stuff.

The application of heat to a mixture of rubber and sulphur was called vulcanizing, after Vulcan, the ancient Greek god of fire. Goodyear found that by varying the amount of heat for the mixture, he could make rubber soft or hard.

Because he had finally come to be denounced as a man who neglected his family in pursuit of a foolish idea, Goodyear had some difficulty in making people believe that he at last had succeeded in making rubber valuable. It was after many discouragements that he finally succeeded in finding a man in New York City who had faith enough in him to enter into a partnership for manufacturing rubber articles. When this was accomplished, he began to place rubber goods on the market and to reap some financial rewards for his years of discouraging labor.

Goodyear received at European expositions a number of medals in honor of his work with rubber. One of these was presented at an exposition in London in 1851, and another in Paris in 1855. He might have been a very wealthy man if he had been satisfied to have done nothing further except to share in the profits of companies protected by his patents. His one passion, however, was rubber, and every bit of money that he made went to financing more experiments on various rubber articles. He is said to have thought of and worked out more than two hundred different uses of this material. When he had perfected a certain rubber article so that it was ready to be marketed, he lost interest in it, like the true inventor that he was, and turned his attention to some new use of rubber.

SULPHUR IN ANCIENT TIMES

Sulphur is quite as important in the making of finished rubber as the latex or rubber sap itself. Sulphur was known in ancient times and was called brimstone, or at least the word used for it was translated as brimstone, which comes from the Anglo-Saxon *bren-stone* or "burning stone."

The Bible gives a number of references to brimstone. Thus in Genesis 19:24 we read: "Then the Lord rained upon Sodom and upon Gomorrah brimstone and fire from the Lord out of heaven."

Again in Deuteronomy 29:23 the following passage is to be found: "And that the whole land thereof is brimstone, and salt, and burning, that it is not sown, nor beareth, nor any grass groweth therein, like the overthrow of Sodom and Gomorrah."

In Job 18:15, speaking of the calamities of the wicked, it is said: "Brimstone shall be scattered upon his habitation."

Again in Psalms 11:16 David recites his belief in what God will do with the wicked: "Upon the wicked he shall rain snares, fire and brimstone, and an horrible tempest: this shall be the portion of his cup."

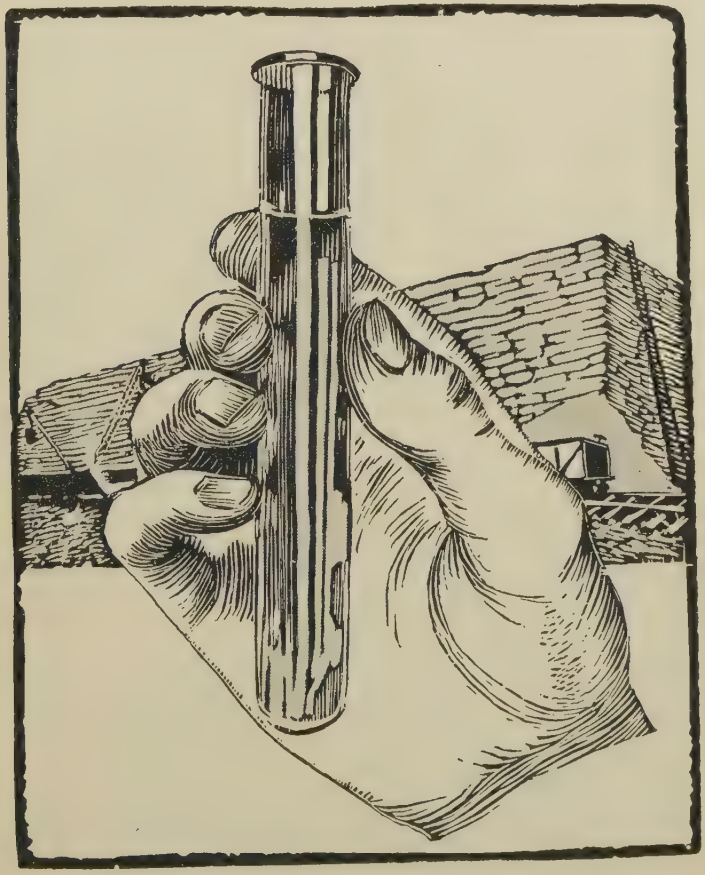
Other similar references are found in Isaiah 30:33 and 34:9; Luke 17:29; and Revelations 9:17, 14:10, 19:20, 21:8.

MODERN SULPHUR MINING

Twenty-five years ago all of the sulphur brought into the United States came from Sicily or Japan. To-day we mine all that is needed for our own use, with some to spare for exportation. Our modern supply of sulphur comes from beds one thousand feet below ground.

"This change was brought about," writes W. T. Lundy, production manager of the Freeport Sulphur Company in the *Chemical and Metallurgical Engineering Journal,* "by the discovery . . . of sulphur in the caprock overlying the salt domes in the oilfields of Louisiana and Texas. In the first attempts to

obtain this sulphur ordinary mining methods of shafts, levels and stopes were employed, but the poisonous gases encountered made them failures. Herman Frasch took out patents in 1891



FROM TEST TUBES TO TONS

The student of chemistry studies sulphur in test tube proportions. The sulphur producer works with it in quantities the size of a cliff.

covering a method of heating water to about the melting point of sulphur, forcing it down drilled well-holes and into the porous sulphur-bearing rocks and then bringing the molten

sulphur to the surface by air lift. It took the Union Sulfur Company, the first operator, twelve years to perfect the process to a point where these deposits were any factor at all in the world sulphur market."

THE SULPHUR KING

Herman Frasch, the man who became king of the sulphur industry, was born in the year 1852 in Gaildorf, Württemberg, Germany. He took up the practice of pharmacy at the age of sixteen, but sailed for America soon after this. He landed in Philadelphia and obtained a position in the Philadelphia College of Pharmacy as laboratorian.

At twenty-two Frasch became more deeply interested in industrial than in pharmaceutical chemistry. As a result, he set up a laboratory of his own and began some private investigations. His first patent was taken out in 1875 on a process of utilizing tin scrap. His second invention, completed one year later, revolutionized the method of refining paraffin wax, and was purchased by one of the subsidiary companies of the Standard Oil Company.

During the next nine years, Frasch was associated with the development of the oil industry. At the same time he found it possible, in addition to his regular work, to invent a process for making a kind of white lead directly from galena, one of the commonest lead ores; for improving methods of manufacturing salt; and for making improvements on certain electric appliances.

Frasch heard in 1891 of the deposit of sulphur in Louisiana. He had made money in the oil business, and the experience that he had had in this industry made him keenly interested in mineral deposits of all kinds, liquid and solid.

The sulphur fields of Louisiana had been discovered in 1865 by oil prospectors. Nearby beds in Texas were discovered somewhat later. Whereas the Sicilian sulphur beds were not so

far underground that they could not be reached by sloping adits and mined with pick and shovel, the Louisiana mines are one thousand feet below the surface, filling what seemed to be the cone of some great geyser that had been active in prehistoric times. Above the sulphur bed is a layer of quicksand five hundred feet deep, which defeated every early attempt to get at the sulphur. An Austrian company, a French company, and several American companies had tried in succession to sink shafts for getting at the material in the regular way, but without success.

When the perplexing problem of how to get the Louisiana sulphur to the surface of the earth first came to Frasch's attention, he gathered all available data and set to work on the problem.

"I decided," he said, "that the only way to mine this sulphur was to melt it in the ground and pump it to the surface in liquid form."

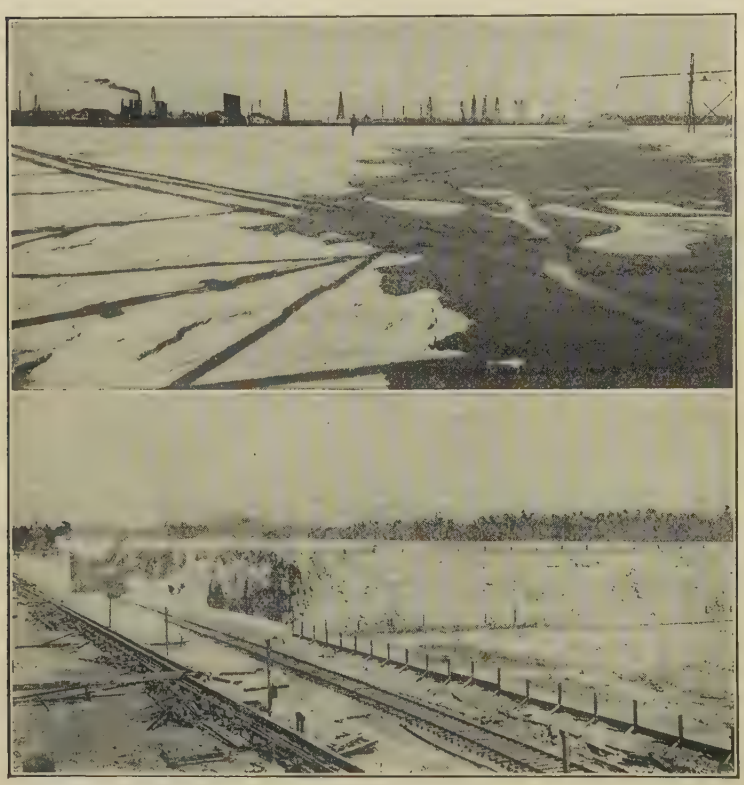
Because drilling equipment was crude in those days, nearly nine months' time was required to sink a ten-inch pipe to a sufficient depth to be of any use. Three days is required now for this same operation. Inside the ten-inch pipe Frasch placed a six-inch pipe, within which a third pipe, three inches in diameter, was placed. He packed the space between the two larger pipes with sand to brace it against pressure of quicksand and shifting rocks.

It was Frasch's plan to force down water, superheated because of the pressure on it, between the six-inch and three-inch pipes. With this in mind, he installed twenty 150-horsepower boilers, together with some superheating cylinders which he himself had devised. Water was forced down steadily for twenty-four hours, at which time the engine attached to the sulphur line was started.

"More and more slowly," said Frasch, "went the engine; more steam was supplied, and at last the man at the throttle sang out at the top of his voice, 'She's pumping!' On the

polished rod of the pump appeared a liquid and when I wiped it off with my finger I found my finger covered with sulphur."

Fifteen minutes later the golden fluid was being pumped into barrels which had been set for the purpose. The forty odd barrels proved inadequate, and the workmen quickly threw up



Courtesy Union Sulphur Co.

A MODERN SULPHUR PLANT

Above, discharge of melted sulphur; below, breaking up and loading sulphur from the hardened pile.

embankments and lined them with boards. From this first day on, no further attempt was made to catch the melted substance in vessels of any sort.

The pumps were shut down when nightfall came, and the workmen busied themselves with pick and shovel, removing the pile of hardened sulphur which had accumulated and building a new bin to receive the next day's supply. When every one but the inventor had gone home, he is said to have climbed onto the heap of piled-up sulphur that had been brought up during the day and have sat there for several hours exulting over the success of the venture and figuring on necessary improvements on the process.

With all the initial success that the Frasch method of mining sulphur experienced, twelve years were required before the method was placed on a paying basis. It is one thing to have a method that works and another to have a method that yields a product that can be sold at a profit. Between the first experiment and final industrial success lay years of hard fighting against minor difficulties.

In 1912 Frasch received the Perkin medal, which represents in America the highest recognition an industrial chemist can win from his fellows.

USES OF SULPHUR

The sulphur used in the United States is distributed about as follows:

	Per Cent
Drug store	.00089
Fumigating and bleaching	1.4
Spraying and dusting	2.7
Rubber industry	3
Explosives (this includes the amount first converted into sulphuric acid and then used to manufacture explosives)	4.3
Paper industry	18.2
Manufacture of sulphuric acid	70.4

The 70.4 per cent of sulphur that finds its way into sulphuric acid is distributed among the different industries as follows:

	Per Cent
Textile industries	1
Paint industry	2
Steel pickling	6
Metallurgical purposes and batteries	6
Manufacture of chemicals	11
Oil refining	14
Manufacture of fertilizer	25
Miscellaneous	6

BACK AGAIN TO THE RUBBER PLANT

Our consideration of sulphur has taken us far away from the subject of rubber; but that is the way with things. When we track down all the kinds of stuff used to make some common article, we are very often taken far afield from our original subject.

The first step in the production of vulcanized rubber is in securing the crude gum. The gum is prepared from a milky substance or latex which comes from certain trees growing in tropical countries. This substance is another of the many compounds of carbon, hydrogen, and oxygen, and it is supplied to the tree for the purpose of protection. When the bark of a rubber tree receives a slight injury, a small amount of this liquid seeps through the opening and hardens after it is exposed for a time to the air. This covers the injured spot in the bark with a thin film which serves as a protection until the bark has had a chance to heal.

Since the liquid from which rubber is made comes from tubes that run up and down throughout the inner bark of a tree, it may be gathered by making gashes across the bark and catching the liquid as it very slowly oozes forth. In tropical regions, wild trees are tapped by the natives. Cultivated trees likewise are grown on well-cared-for plantations.

In regions where natives collect rubber from uncultivated trees, the liquid is hardened over a smoky open fire covered

with a crude inverted funnel so that the smoke may issue through the opening at the top. A long pole is suspended over this smoking fire, and a small amount of the thick liquid is carefully poured around the middle of the stick, which is rotated in the smoke. After the liquid hardens to a gummy

FACTORY TREATMENT OF CRUDE RUBBER

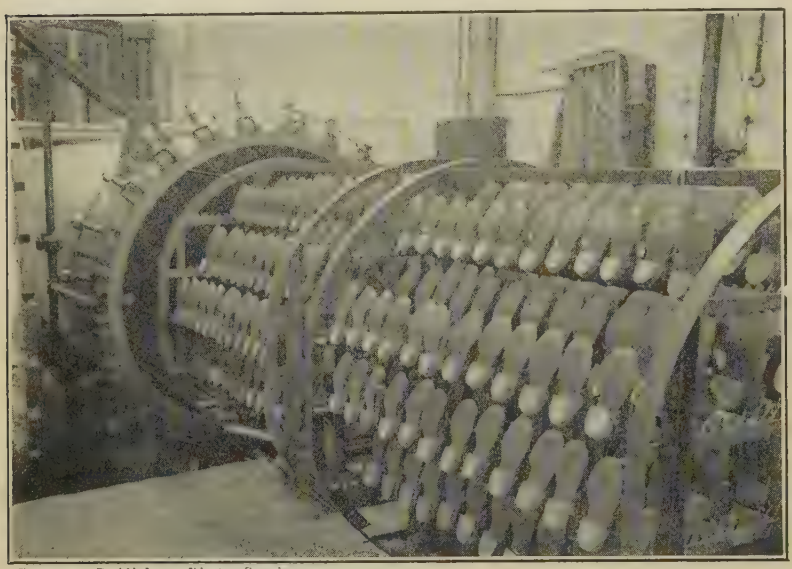
When it reaches the manufacturing plant, it is washed and dried in large vacuum ovens.

substance, another layer is poured on and smoked, and another and another until a huge ball is formed.

On the plantations, the liquid as it comes from the rubber tree is hardened by adding acids to it. The coagulated gum which results from this treatment is then run through rollers. The sheets thus formed are hung in a smoke house and smoked in somewhat the same way as country-cured ham.

USES OF RUBBER

Though waterproof wearing apparel is one of the most practical and interesting uses of rubber, because it adds a great deal to our comfort on stormy days, this takes only a small part of the raw rubber produced. The place where most of the



Courtesy Publishers Photo Service

FOR STORMY DAYS

Rubber shoes are run into an oven to undergo vulcanization, or reaction of the rubber molecule with sulphur.

rubber goes is easy to guess when we consider the number of motor cars turned out each year, every one of which rolls on rubber. An English rhymster, inspired by the importance of the rubber tree to mankind because of this use, wrote the following for *Punch:*

> For centuries a tropic plant
> Obscure and insignificant,
> Common to both worlds, West and East
> I did no good to man or beast.

Yet now my rich and viscous juice,
Turned to a locomotive use,
Has lent the rigid chariot wheel,
The limber movements of the eel.
And oils that kindle and explode
Have made me monarch of the road.

Rubber has hundreds of uses other than those already described, and for nearly every one there is nothing else that would serve so well. In fact, it is perhaps correct to say that there are thousands of uses for the coagulated "rich and viscous juice" of the tropic plant. For example, rubber washers and gaskets in spigots, rubber rings on fruit jars, rubber heels and soles on shoes, rubber aprons in the chemical laboratory, rubber gloves for surgeons and electricians, rubber toys for children, rubber in tennis balls for boys and girls, rubber golf balls for their fathers, rubber bands for parcels, rubber tubing for chemical apparatus, rubber insulation on electric wires, rubber sponges for the bath, rubber jewelry for bathers, hard rubber in combs, fountain pens, brush handles and backs, buttons, telephone receivers—all these are everyday uses that every one is familiar with. Any one looking up from his reading and without so much as turning his head very likely can see one or more articles made of rubber.

In fact, it is easier to think of fifty articles for which nothing but rubber could be used than to think of half as many things for which rubber could not be used at all. One might suggest that rubber would not be fit for paving streets. But rubber already has been used successfully for this purpose. The item of cost is the only drawback.

At first thought, rubber would not seem to be a good material for making furniture, but vulcanized hard rubber has already been used to imitate different kinds of hard woods. The only reason why rubber is not used at the present for making articles of any great size is the prohibitive cost.

The objection of high cost, which now prevents the use of

FINAL INSPECTION OF RUBBER TIRES

rubber in many places, will very shortly cease to be raised, in the opinion of many scientists. Chemists are now able to make artificial substitutes for rubber, some of them quite similar to the natural product. As soon as they perfect the process further, we shall see a great number of surprising new uses for this already important material.

Another field in which the rubber chemist is now working is in the processing of rubber latex. He has found out how to add alkalies to latex so as to ship it in the liquid form, and how to waterproof wood and other materials by the direct application of this unhardened product. The discovery of means of using rubber latex directly is one of the triumphs of modern science.

"At least," some one may say, "rubber cannot be used as an

article of food." This, of course, is true. Not long ago, however, a chemist succeeded by a special process in modifying the texture of rubber so that it would absorb some sugar solution and fruit flavoring, and from it he made a very satisfactory chewing gum.

THE ALCHEMIST

CHAPTER XII

THE SCIENCE OF STUFF

The sinful sons of Adam . . . by a piece of the divel's chymistry turn their necessity into delight, and make their curse their blessing.
—T. Wall (1658)

THE science that deals with the composition of such things as air, water, the halogens, foods, fuels, phosphorus, and sulphur is called chemistry. The Egyptians were among the earliest races of people that made new discoveries concerning materials they could use to satisfy their needs and to give them comforts and luxuries besides. It is quite fitting, therefore, that the word *chemistry* should be of Egyptian origin. *Chemi* was an old native word for Egypt.

It meant "black," and was applied to that country because of the blackness of the soil. The word *chemistry,* although of modern origin, comes from this ancient Egyptian word *chemi.* Some language specialists think that it means "the Egyptian art," because the Egyptians were the forerunners of the modern chemists. Others think that the original meaning of chemistry was "the black art," because of the dark mysticism that surrounded the ancient and medieval scientists.

We have seen how the ancient races of people made accidental discoveries concerning the uses of a few materials. Any knowledge that they stumbled upon they preserved by rule of thumb. The advancement they made was limited because they knew nothing of the actual nature of the changes taking place when they carried out a certain operation. The progress made by the most ancient races was also independent of that made by any of the other races at the time. Means of communication between the various parts of the world had not yet been established, and each race was left to work out its own problems without any help from outside sources. It is interesting to note, however, that even before different countries had any means of carrying on intercourse with each other, peoples living far apart have made almost identical discoveries.

THE PHŒNICIANS, PEDDLERS OF MERCHANDISE AND INFORMATION

At a very early time there began to be an exchange of ideas between different countries. People began to build wooden ships and to trade with each other. Particularly was this true when the Phœnicians, that oldest of seafaring nations, began to go from country to country and to sell the products of one land to the people of another. While peddling their wares the Phœnicians also dispensed much free information of one sort and another. This race of people might truly be called the broadcasters of information of ancient times.

GREEK YOUTHS GO TO EGYPT TO BE EDUCATED

The Greeks, who reached the height of their culture fully fifteen to twenty centuries later than the Egyptians, borrowed much of the knowledge of this older race and carried it to Europe. They succeeded in accomplishing this in two ways. In the first place, all of the wealthy Greeks sent their sons to Egypt to be educated. These Grecian students learned much of what the Egyptians knew of materials and how to prepare and use them. The few secrets which the Egyptian priesthood kept from the students whom they taught were obtained by some means or other by Greek philosophers and scientists who traveled in Egypt.

From Greece the science of materials in ancient times filtered into other parts of Europe. Because the methods of travel and communication were painfully slow then, a century or so was required to spread abroad a bit of information which would now reach around the world in twenty-four hours.

THE RISE OF ALCHEMY

Dating from about the first century A.D., the learned men left off their search for practical methods of making materials which might have an important everyday use. They began to devote their time to the study of how to get rich quickly. Some one about this time declared that it might be possible to change a cheap metal, such as lead, into a precious one, such as gold.

All of the other learned men of the day took up the idea, and almost every study was abandoned except that of transmutation, or the changing of one metal into another. It was thought that some mysterious substance whose nature was not known might be found which would assist in this undertaking. This vague and mystical substance for which all philosophers began searching was called the Philosopher's Stone. Consequently,

every material that the investigator could lay his hand on was tried out to see whether or not it might prove to be this imaginary Philosopher's Stone. All of these substances undergoing examination were hammered and heated in the presence of lead or some other cheap metal, in an effort to produce gold.

A FAD FOR FIFTEEN CENTURIES

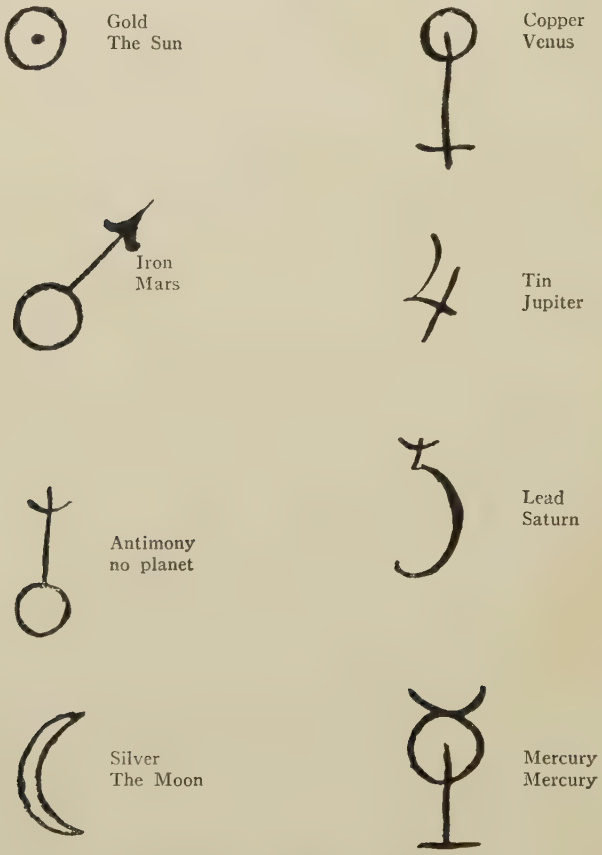
The men who were trying to bring about transmutation were called alchemists. The transmutation fad was not like our modern crazes, forgotten in a very few months; it lasted for something over fifteen hundred years. During this time the best educated men of every country were giving this problem their chief attention. As a result, the science of stuff was almost at a standstill, since the only new substances which were discovered were used for trying to change cheap metals into gold and not for improving the conditions of everyday life.

It is a matter of wonder that the alchemists thrived for more than fifteen centuries, since none of them succeeded in what they set out to do, and none of them did anything else that was of very great importance. They were not school teachers, and they had no other occupation except that of alchemy.

The reason for the long reign of prosperity of the alchemists in the face of their failure, however, was simple enough. Some of them had sufficient wealth of their own to make it possible for them to spend their entire time at a task from which they earned nothing at the time but from which they hoped some day to reap large rewards. Others were endowed by wealthy patrons who hoped at some time to get five hundred per cent return from their investment. But by far the greater number of them were retained as members of a king's court.

All of the kings of Europe supported a number of their own private alchemists. Each king believed that one of his own number would find the mystical secret and turn fabulous wealth into the coffers of the court. Of course each of the

royal alchemists was obliged to keep up the appearance of making progress in order to keep his job. For this reason he frequently gave performances before the king and the court.



SYMBOLS OF THE ALCHEMIST

Sol gold is, and Luna silver we threpe,
Mars iron, Mercury quicksilver we clepe,
Saturnus lead, and Jupiter is tin,
And Venus copper, by my father's kin.

At these performances the alchemist did a number of tricks with acids and brightly colored solutions, and thus convinced the king that he had supernatural power over the stuff with which he was experimenting.

TRICKS IN ALL TRADES

Some of the alchemists were undoubtedly sincere, and mistook chemical happenings which we now explain without difficulty for actual transmutations. Others deliberately practiced deceit in order to impress their patrons. Here are some of the tricks of dishonest alchemists:

Use of double crucibles.

Practice of putting salts of gold or silver in the bottoms of crucibles, and then covering them with a paste of crucible dust and wax which melted during the experiment.

Practice of burying gold or silver dust in a hole in a block of charcoal.

Use of rods with hollowed ends filled with gold or silver powder.

Practice of producing amalgams and alloys of about the same color as silver.

ALCHEMISTS AND HENRY VI

Henry VI of England was one of the kings of the period from the fifth to the seventeenth century who employed alchemists. This monarch had enough experimenters to keep a modern research laboratory going. Although these men knew nothing about chemistry, they duped the king, and perhaps even themselves, into thinking that they had prepared gold by putting mercury and blue vitriol into an iron crucible with a little water. Any first-year chemistry student to-day can repeat this experiment and reason out the explanation.

Quantities of "false gold" made in this way by the alchemists of the reign of Henry VI were made into coins. The counterfeit was recognized, and prohibitory measures against the circulation of these coins were passed by the Scotch Parliament.

Justus von Liebig, the great German chemist, in his *Letters*

on Chemistry gives us as clear an explanation of alchemy as can be found anywhere:

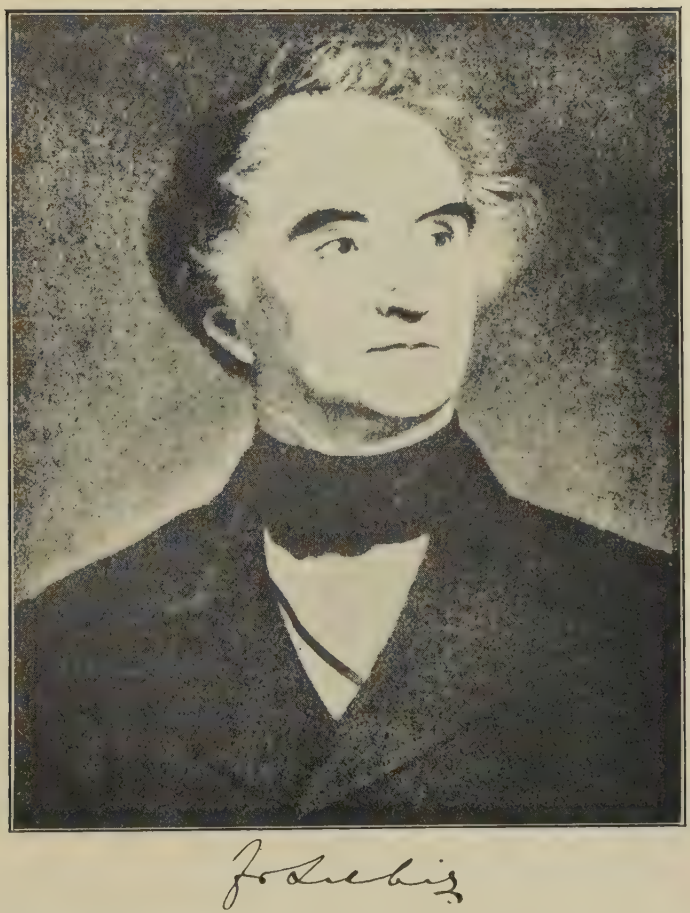
In order to attain that knowledge of chemistry which we now possess, it was necessary that thousands of men, armed with all the science of their respective periods, and inspired with an unconquerable ardour, with a passion for knowledge, which, in its violence, bordered on madness, should devote life, fortune, and their whole faculties, to the task of exploring the earth in all directions. It was necessary that, with indefatigable perseverance and constancy, these men should bring into contact all known substances, organic and inorganic; it was necessary that these labours should be continued for fifteen centuries.

There was, finally, a mighty, an irresistible charm, which urged men to devote themselves with an amount of patience and perseverance altogether unexampled in history, to labours which did not tend to supply any want peculiar to the time in which they lived. This mighty impulse was nothing else than the desire for earthly happiness. . . .

The idea of the philosopher's stone, considered as a means of transmuting the baser metals to gold, was spread abroad from Egypt, chiefly by the Arabians. By the conquest of Egypt, they acquired possession of natural and scientific truths, perhaps originally attained by a jealous caste of priests, and which, being taught as mysteries in the temples, were accessible only to the initiated. Even Herodotus and Plato had early obtained instruction and knowledge in that remarkable country.

Nine hundred years before the conquest of Egypt by the Arabs, the Alexandrine Academy already supplied a centre of scientific activity, and even down to the period of the burning of the vast library by the Arabs, Alexandria was the seat and the refuge of Grecian science. Among the Arabs, a people intellectually new and fresh, whose Mahometan fatalism was opposed to the development of medicine, and whose maxims, derived from the Koran, expressly prohibiting research and reflection, were yet unable to check the progress or prevent the encouragement of the sciences of medicine, astronomy, and mathematics; among these Arabs the views of the Alexandrian philosophers concerning the transmutation of metals found a prepared and fruitful soil ready for their reception.

At the time when Bagdad, Bassora, and Damascus were the centres of the commerce of the world, there was no nation more



JUSTUS VON LIEBIG, THE GREAT GERMAN PIONEER IN CHEMISTRY

dexterous or more active in trade, or more eager for gain and gold, than the Arabs. Their tales and legends have preserved for us the favourite dreams and desires of that period, which were the motives of Arabian enterprise and activity. While the elves and nixes, the dwarfs and Undines, of the Germanic legends, appear as the bestowers of swords which no foe could withstand, or of unguents which healed every wound; of wine-cups full or of tables over-loaded with food; the genii of the Thousand and One Nights are always the

guardians of immeasurable treasures of gardens, whose trees are of gold and their fruits of precious gems. . . .

From the Arabian universities, the endeavour after the discovery of the philosopher's stone, and with it, the acquisition of chemical knowledge, and the whole direction given to scientific research, was communicated to the north-west of Europe.

The writings of Geber, the Pliny of the eighth century, give evidence of an extent of chemical knowledge, of facts experimentally established, which, when the period is considered, excites our wonder and admiration; and the theories of the great philosophers of the thirteenth century, Roger Bacon and Albert von Bollstadt (Albertus Magnus), Bishop of Ratisbon, may, for their fertility of ideas, and their comprehensive views of nature, be fitly compared only with those of the modern schools of natural science. . . .

Previous to the invention of printing, it was easy for an alchemist to keep secret his discoveries. He exchanged them only for the observations of other adepts. The chemical processes which they published are clearly and intelligibly described, in so far, at least, as they are not such as to lead to any practical result in reference to the chief object of their search; but they expressed their views, and described their labours, on the subject of the grand arcanum or Magisterium, in figurative language and in mysterious symbols. They propounded in an unintelligible language that which, in their own minds, was only the faint dawn of an idea.

That which chiefly excites our wonder is, that the existence of the philosopher's stone should have been regarded, for so many centuries, as a truth established beyond all doubt, while yet no one possessed it, and each adept only maintained that it was in the possession of another. . . .

During the sixteenth century alchemists were found in the courts of all princes. The Emperor Rudolph II and the Elector Palatine Frederick were known as patrons of alchemy. Men of all ranks studied transmutation, and strove to attain possession of the grand arcanum. Just as in the present day vast sums are expended by princes, private persons, and associations in mining enterprises for the discovery of metallic ores, of coal, or of strata of salt, so were vast sums squandered in the sixteenth and seventeenth centuries for the researches deemed necessary in order to discover the philosopher's stone. A multitude of adventurers appeared, who endeavoured, at the courts of the great and mighty, to pass for adepts, that is, possessors of the secret; but this was a dangerous game: for those

who at one court, or at another, succeeded, by dexterously managed transmutation, in establishing their character as adepts, and carried off honours and riches as their reward, were sure finally to fail elsewhere; and their end commonly was, to be hung in a robe covered with tinsel on a gallows adorned in a like manner. Those, again, whose imposture could not be proved, expiated the fatal honours of being believed to possess the philosopher's stone, under the hands of covetous princes, by imprisonment and tortures. Indeed, the cruel treatment which such adventurers experienced was regarded as the strongest proof of the truth of their art.

From about the fifteenth to the sixteenth century many of the alchemists left off their search for a method of changing lead into gold and took up a new fad. The new idea was that of searching for a substance that would give human beings the joy of everlasting existence on this earth, or at least the boon of youth for a hundred years or so. Of course this search also proved to be fruitless, and the alchemists gradually became less popular during the sixteenth and seventeenth centuries.

GIVING THE ALCHEMIST HIS DUE

It really seems a shame that during fifteen hundred years hundreds of the brightest minds of the age were devoted to a foolish search for a fictitious philosopher's stone. What might have been accomplished during that period if all of this effort had been directed toward straightforward scientific research! But because of the kind of a game that every one was playing, the sum total of the results was almost nothing at all. Nevertheless, one group of discoveries was made which justified alchemy to some extent, and that was the finding out methods of making strong acids.

The need of strong reagents for getting minerals and metals into solution led to the discovery of the three most important mineral acids—sulphuric, nitric, and hydrochloric.

Vinegar was the chief acid of the ancients. The word *acid* comes from an Old English word for *vinegar,* which in turn

comes from a Greek word meaning "edge." The fact that vinegar had a sharp and "edgy" taste was therefore accountable for its name. But vinegar was not sufficiently edgy for the alchemists.

SULPHURIC ACID

An Arabian alchemist of the eighth century, who was called Geber by the European writers, was the first to prepare a really edgy acid. This was sulphuric acid, which is well known to all who have carried on any first-hand investigations with storage batteries.

From Geber's time until 1746 sulphuric acid was made by the ignition of iron sulphate or alum, the two chief salts of this acid known to the alchemists.

In 1746 John Roebuck invented the lead-chamber method of making sulphuric acid. In this process nitrogen oxides serve as catalysts to bring about the combination of sulphur dioxide with an additional atom of oxygen per molecule. The resulting sulphur trioxide is dissolved in water, giving sulphuric acid. The resulting acid has a concentration of 60 to 70 per cent sulphuric acid. This was formerly concentrated by heating it in platinum vessels. More recently, however, fused silica vessels have superseded to some extent the more expensive platinum crucibles.

A newer process for producing sulphuric acid was introduced a few years ago and was brought into prominence during the war because of the fact that it produced directly a very concentrated acid. This is called the contract process. It depends upon the property of finely divided platinum of catalyzing the addition of oxygen to sulphur dioxide.

For the contract process, sulphur dioxide is produced by the roasting of pyrites. This is mixed with air and led over platinized asbestos, platinized iron oxide, platinized silica gel, or, more recently, vanadium sponge, at a temperature of 400°

to 500° centigrade. The resulting sulphur trioxide is passed into dilute sulphuric acid until the latter becomes concentrated.

Sulphuric acid is variously called the "king of chemicals," the "old horse of chemicals," the "barometer which measures the industrial progress of nations," and the "vital fluid of the nation's business."

The first large-scale plant for the production of sulphuric acid was built in 1746 in Birmingham, England. The lead-chamber process was used. The first sulphuric acid plant built in the United States was constructed in Philadelphia in 1793 by John Harrison. Harrison's plant produced a carboy of the acid a day.

NITRIC ACID

Nitric acid was known at an earlier date than was sulphuric acid, but it did not come into general use by the alchemists until some centuries after it was discovered.

Dioscorides, an early Greek writer, is the first to describe a method of making nitric acid, the method being the distillation of a mixture of saltpeter, blue vitriol, and alum. In all of the early writings nitric acid was called *aqua fortis,* or "strong water." Laboratory students of the present time who have been so unfortunate as to spill some of this liquid on their hands can readily testify as to the appropriate character of the name.

Johann Rudolph Glauber, a German alchemist living from 1604 to 1668, was the first alchemist to mention preparing nitric acid by the action of sulphuric acid on a nitrate. Another contribution of Glauber was the preparation of crystalline sodium sulphate, now called Glauber's salt.

Although statistics are to be shunned by every one except professional economists, it is interesting to note how nitric acid is used industrially. Of the more than 100,000 tons of nitric acid consumed annually in this country, the following is the distribution of uses:

	Per Cent
Manufacture of explosives	75
Manufacture of imitation ivory and other plastics	10
Manufacture of chemicals and dyes	8
Manufacture of lacquers	5
Other uses	2

AN ALCHEMIST-MONK DISCOVERS HYDROCHLORIC ACID

Basil Valentine, a monk who followed alchemy and made many important discoveries during the late fifteenth century, was the first to describe the preparation of aqueous hydrochloric acid, which he made by heating a mixture of salt and iron sulphate, and dissolving the gas formed in water. Valentine also described a mixture of this acid with nitric which he called *aqua regia*. The term was concocted because of the fact that this combination of acids will dissolve gold, the king of metals.

With the introduction of acids, the alchemists were able to produce a great number of salts which they made use of in their investigations.

FROM TEST TUBES TO TONS

Whereas Valentine and his contemporaries were content to distill a few test tubes (or whatever they used in those days instead of test tubes) full of hydrochloric acid at a time, this acid is now made in quantities of thousands of tons a year. The hydrochloric acid produced in this country is made use of approximately as follows:

	Per Cent
Manufacture of heavy chemicals	23
Manufacture of iron and steel	19
Manufacture of fine chemicals	14
Manufacture of textiles	11
Manufacture of dyes	6
Manufacture of soap	3
Manufacture of glucose	8
All other uses	8

THE PASSING OF ALCHEMY

The alchemists were followed by a group of scientific men who no longer hunted for a substance that would change base metals into precious ones, or which would make human beings able to live indefinitely. These new scientists set out to study the composition and possible uses of all sorts of materials. This advanced class of thinkers worked hard and studied much. They kept none of the older notions of miraculously obtaining fabulous wealth or of prolonging life. They began an earnest search for the true reason for the behavior of substances, with the idea of learning better how to make use of these materials for everyday purposes. To this class of thinkers, the name *chemists* gradually began to be applied.

ROBERT BOYLE

The year 1627 marks the birth of the pioneer of modern chemists. Robert Boyle, who lived from 1627 until 1691, was an Irish nobleman and the first person of his time to take what might be called a sensible view of the composition of materials.

Boyle was the seventh son and the fourteenth child of the great Earl of Cork, Richard Boyle. Being a well-educated younger son of a member of the peerage, he found himself without anything to occupy his time except what he should choose for himself. The oldest brother inherited the estates, so no responsibility in this direction fell upon young Robert. To go to work was out of the question for one of his rank. The natural thing would have been for him to have divided his time between the British Isles and the Continent, seeking amusement wherever he could find it. Robert was an ambitious youth, however, and he had a different idea of the way in which he would spend his time. He early showed a great interest in science, and when he came of age he used his money

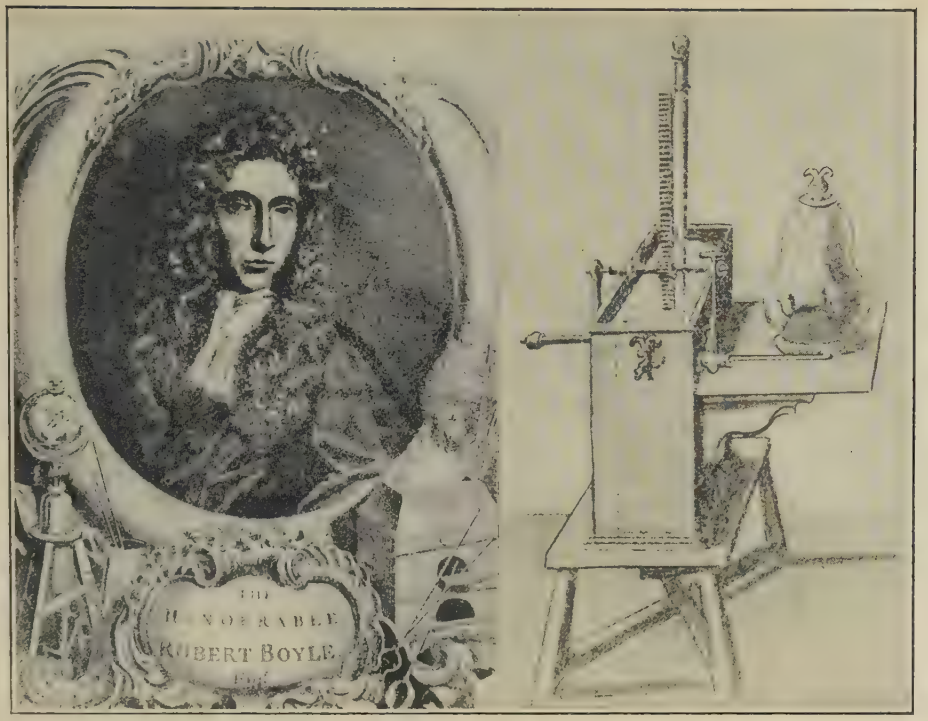
to set up a private laboratory to study some of the problems which long had interested him.

Boyle was not satisfied with the vague and mysterious teachings of the alchemists concerning the composition of substances. These men named various substances after the stars and planets, and they believed that these substances were guided in their behavior by the dictates of their patron planets. Of the actual composition of substances they knew nothing at all.

Boyle was the first person to believe, as we do to-day, that all substances fall into two classes, called elements and compounds. Boyle's reason for this belief was the fact that some substances such as iron, silver, lead, and gold resisted all of his attempts to split them up into simpler substances. To such materials he gave the name of elements. Other substances were able to be decomposed into the two or three elements of which they were composed. These substances he called compounds.

Boyle not only started the ball rolling in the right direction as regards the actual composition of common materials, but he also began the first sensible study of the reason why substances behave as they do. This scientist classified all the elements and compounds he knew, which was small indeed, into gases, liquids, and solids. Substances such as air he called gases. Substances such as water and mercury he called liquids. Gold, salt, and stone he called solids. Boyle's interesting experiments with gases are well known by every young science student.

Boyle was followed shortly by such pioneer chemists as Priestley, Lavoisier, and Scheele. These men went even further than Boyle and showed that elements do not combine with each other in a haphazard fashion, but in a very definite and orderly way. Thus the compounds which they analyzed proved always to be composed of the same elements combined always in the very same proportion by weight.



SIR ROBERT BOYLE, FATHER OF CHEMISTRY BOYLE'S AIR PUMP

LAVOISIER

Boyle was the first scientist to give a clear-cut meaning to such terms as *element, compound, solid, liquid,* and *gas.* Priestley and Scheele gave an impetus to the newly developing science of chemistry by discovering a large number of hitherto unknown substances. But it remained for Antoine Laurent Lavoisier, a French scientist, to give the proper interpretation of many preceding discoveries by the introduction of quantitative experiments.

In 1770 Lavoisier showed that when water boils, it is not transformed into earth as was previously believed. He demonstrated this fact by boiling water in a sealed tube so that none of the steam could escape. In a similar way he showed that substances, when burning, actually took on oxygen of the air. He thus upset the old phlogistic theory of burning.

"Lavoisier discovered no new body, no new property, or no natural phenomenon previously unknown," said Liebig, the German chemist, in his *Letters on Chemistry.* "His work was to interpret the discoveries of those who had gone before him in the light of quantitative measurements."

Lavoisier was a contemporary of Priestley and Scheele, although he was ten years younger than the former and one year younger than the latter. He was of wealthy parentage, and received a splendid education in the various sciences. When he was but twenty-three, he received a medal for the best essay on how to light a city. Later he became interested in agriculture to the extent that he started a model farm and demonstrated the advantages of applying scientific methods to farming. He was instrumental in the establishment of the first agricultural experiment stations. He was also made chief director of the saltpeter industry, of which the government had a monopoly. In this capacity he made valuable improvements in methods of producing saltpeter and gunpowder.

At the age of thirty-eight and in the midst of his scientific

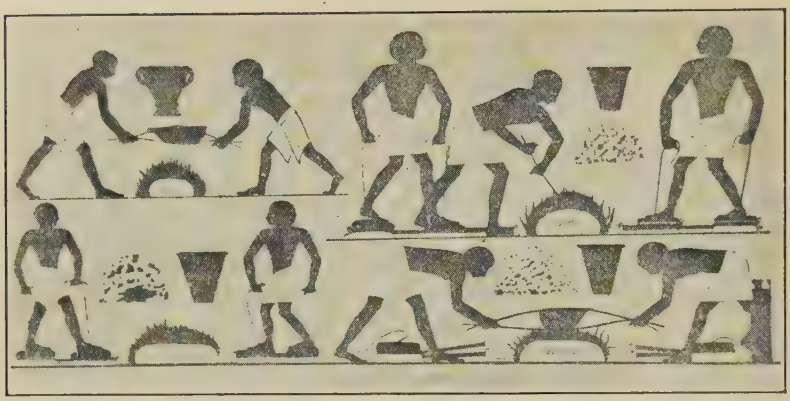
career he became involved in political difficulties with the revolutionary régime. Three years later he and twenty-six of his associates were guillotined.

"It required but a second to take off his head," said a writer of the time, "but it will take a hundred years to grow another like it."

CHEMISTRY AND BALANCES

After it was found that substances behave in definite ways and that they never vary from this behavior, there was no longer any need for guesswork in the study of materials. Scientists thereupon began to weigh the materials that they worked with and to calculate with absolute accuracy the outcome of a certain treatment of these materials. With the introduction of the use of definite mathematical calculations in a study of elements and compounds, modern chemistry was born.

With the use of simple arithmetic and scales for weighing, the modern chemist can do more wonderful things than those which the alchemist tried and failed to do. The modern chemist discovers new materials which have hitherto been locked up among Mother Nature's secrets, some of these being much more valuable than gold. The modern chemist also finds new uses for substances already known, and thus brings more happiness to human beings than the alchemist could have done if he had found an everlasting source of gold or youth. He even does more than the most altruistic of the alchemists, for instead of carrying on a hopeless search for a mystical substance which might prolong human life, the modern chemist conducts a scientific study of food properties and medicines, and thus helps to lengthen life by rational means.



Courtesy Metropolitan Museum of Art

WORKSHOP OF ANCIENT BRONZE FOUNDERS
(From an Egyptian tomb painting, Rekh-my-Re, 1471 to 1449 B.C.)

CHAPTER XIII

CAULDRONS, COINS, CORNICES, AND CABLES

They boiled it in a copper to the half.
—BACON
My friends filled my pockets with coppers.
—FRANKLIN

APPLE-BUTTER KETTLES

THE practice of making apple butter in a copper kettle over an outdoor fire is quite common in some parts of America. In such communities, the one or two housewives who own copper kettles lend them all over the neighborhood during the apple-butter season, and the boys in these communities have to stir apple butter throughout many an autumn Saturday when they would doubtless much rather be hunting partridges or playing shinny with the village gang.

In our grandmothers' and great-grandmothers' time, the practice of making apple butter in large quantities at home was much more common than it is at present. In those early days there was probably not a single boy who did not have the stirring of apple butter as one of the labors which annually

tried his soul. The utensil used for this operation was always a bright and shining copper kettle. Although few people knew the scientific reason for the superiority of copper for this purpose, they all knew by experience that it actually was better in every respect than iron. Iron, they found, darkened the butter and gave less satisfactory results generally. We now know that the scientific reason for this difference is that copper is quite inactive chemically, and as a result is not acted upon by the weak acids contained in the apple. Iron, on the other hand, is much more active, and some of it combines with the acids of the apple to form dark-colored products.

THE CHEF'S KETTLE

Even if the old-fashioned copper kettle, sometimes called merely a "copper," is no longer in as common use in the home as it once was, it has been enlarged and glorified in the huge copper cauldrons now employed in the kitchens of hotels, restaurants, and other establishments in which cooking is done by mass methods. The chef in one of these places takes great pride in his shiny copper kettles because he can cook large quantities of food in them without any danger of the foods becoming discolored or otherwise acted upon by the metal.

The use of copper for making kitchen utensils is not by any means modern. One of the earliest uses to which this metal was put was for cooking. In such ancient countries as Egypt, Assyria, Greece, and Rome, copper and bronze were used quite liberally for making pots and pans. Many of these ancient vessels have been recovered from tombs and the ruins of cities, and now can be seen in museums.

ANCIENT SMELTING

Ancient Egypt in the time of King Snefru was probably the first country to begin the practical use of copper. The copper

ore which Snefru's men took from the mines of Sinai and which was most easily smelted in the production of the metal was a bluish-green rock now called malachite. Malachite is a compound of copper in which the metal is combined with the elements carbon, oxygen, and hydrogen. The problem of separating copper from the other elements in the ore is one which chemists work out nowadays in the most careful and scientific manner. The ancient Egyptians, however, knew nothing of elements and compounds. They found out by accident that heating a certain bluish-green rock in the embers of a wood fire succeeded in yielding a lump of reddish metal that they could use. When this information was stumbled upon, people gradually began deliberately to smelt the ore in pits which they dug for the purpose.

A few scattered carvings which have come down to us, together with the ruins of some copper smelting works which have recently been unearthed at Sinai, give us a fair picture of the ancient Egyptian method of smelting copper. From these sources of information we find that the early people first dug a shallow pit in the ground, in which they placed a layer of charcoal. On top of the charcoal they placed the copper ore. Then they lighted the charcoal and awaited results.

The ancients never knew just why copper should result from treating a certain rock in this particular manner. We, however, know that the other elements in the ore are induced by the heat of the fire to part company with the copper and to join with the oxygen of the air and the carbon of the red-hot embers. The compounds which these elements form when they hook up with oxygen and carbon are gases, so they naturally disappear and leave the copper by itself.

BELLOWS

In a copper-smelting operation of this sort, the process frequently slows up for want of sufficient air. Some of the very

earliest smelting operators remedied this trouble by blowing on the red-hot coals with all their might. This was not a pleasant task. Since the bed of coals was very hot, the blowers no doubt frequently singed their eyebrows. In order to bring air closer to the bed of coals without suffering personal discomfort, some ancient genius hit upon the idea of blowing

USING THE BLOWPIPE IN EARLY COPPER SMELTING

through a long tube. This plan worked so well that it was adopted generally, and it remained in vogue in Egypt for more than a thousand years. Finally, about 1500 B.C., one inventor whose name was not recorded but who certainly had more brain power than lung capacity made the first hand bellows. By means of this device, with which air was blown from a bag, probably made of the skins of animals, stretched on a frame, it was easy to supply the smelting ore with a much larger amount of air than was possible by the use of lung power.

The copper made by these early smelting processes was far from pure. Crucibles of ancient origin have been found in Egypt, which show that early attempts were made to refine the crude metal. A crucible is a chemical melting pot made of earth and baked so that it will stand a great deal of heat. A metal may be refined by melting it in a crucible and thus separating it from small bits of rock and other impurities which do not melt. Thus, because of its utility and wide use in smelting, the crucible was the symbol for copper in ancient Egyptian hieroglyphics.

BRASS AND BRONZE

Pure copper, as has previously been mentioned, is too soft to be of much value when used alone. It was not until its two chief alloys, bronze and brass, were first prepared that it came into wide use. Bronze is an alloy consisting of about two-thirds copper and one-third tin; brass, on the other hand, contains about two-thirds copper and one-third zinc. Both of these two alloys were known and used before either tin or zinc were known as separate metals. The two alloys differ from each other in color, bronze being darker and brass lighter than pure copper. They also differ in many other characteristics, and for this reason are suitable for different uses.

BARTERING

An early use of copper and its alloys, and one that has had a great part to play in the development of civilization, was in the making of coins. In the time of our ancient prince and princess, Rahotep and Nefert, and for many years after their day, coins did not exist. Accustomed as we are to-day to money and banks, we find it difficult to realize from what rude beginnings our modern complex commercial system has risen.

When people in ancient times wanted an article that they did not possess, it was necessary for them to exchange some article that they owned for it. Ancient workmen were paid in the products which they helped to make instead of in money. These products they could exchange for the necessities of life as they needed them. This method of trading is called barter.

Barter is still practiced in some uncivilized parts of the world. Thus Lieutenant Verney Lovett Cameron, an English explorer of the nineteenth century, tells of his difficulty in getting a boat in one of the villages of central Africa:

Syde's agent wished to be paid in ivory, of which I had none; but I found that Mohammed Ibn Salib had ivory and wanted cloth. Still, as I had no cloth, this did not assist me greatly until I heard that Mohammed Ibn Gharib had cloth and wanted wire. This I fortunately possessed. So I gave Ibn Gharib the requisite amount of wire; whereupon he handed over the cloth to Ibn Salib, who in turn gave Syde's agent the wished-for ivory. Then he allowed me to have the boat.

The barter system would be even more complicated if we attempted to put it into practice in our own modern civilization. Suppose, for example, that workmen in such industries as those which make steel rails were paid in the products of their labor and were required to use these articles in their daily round of trading with the butcher, baker, and tailor.

MONEY

Even the ancient civilizations were not long in recognizing the clumsiness of the barter system. Instead of exchanging one kind of goods directly for another, it gradually began to be the custom to reckon value through a third medium called money. Copper, and later gold and silver, because of their value and of their convenience in handling, were early found to serve satisfactorily. Instead of having coins of certain known values, the ancient Egyptians had to weigh the metals that they used as money. Ancient Egyptian pictures show people weighing heaps of metal in swinging balances. The metal thus weighed out was reckoned for what it was worth and was used in buying and selling on that basis.

The Hebrews of Bible times also used gold, silver, and copper as money, weighing these metals out on the scales in order to compute their value. In Ezra 8:26, 27 a description is given of how Ezra, the judge, gave money to the priests as an offering, weighing out certain metals in talents (about 90 pounds) and drams (about one-quarter of an ounce) for this purpose:

I even weigh unto their hand six hundred and fifty talents of silver, and of gold a hundred talents.

Also twenty basins of gold of a thousand drams; and two vessels of fine copper, precious as gold.

It was a great deal of trouble to weigh out metals and to test their purity each time a transaction was made. It was therefore strange that the ancient Egyptians or Babylonians did not invent a simpler scheme; but such was not the case. They went on weighing out their money for hundreds of years, with no thought of the simple plan of making coins of definite value.

METAL COINS

The Chinese are thought to be the first people to use coinage. Chinese coins of about 700 B.C. were made of bronze, cut in the shape of miniature shirts, knives, and other articles of everyday use. These were units of value in trading, presumably equal in worth to the articles they represented.

The Greeks were the first people to make coins in any sense similar to our modern pieces of money. The early Greek coins were merely pieces of metal of known purity, with their weight stamped on them. This did away with the necessity of weighing the money each time it passed hands. The Greeks made coins of bronze, silver, and gold. Bronze coins were less valuable than those of the two precious metals, but they were very satisfactory because they could be used by the great mass of the people to buy everyday articles.

The idea of coinage spread from the Greeks to the Romans. The first Roman coins were rough rectangular pieces of bronze weighing several pounds each. They were covered with crude representations of animals. The Romans later developed an elaborate system of coinage which included bronze, silver, and gold pieces. Both the Greeks and Romans began early to decorate their coins with artistic designs.

At the time of Christ, regular systems of coinage were in use

in all civilized parts of the world. In all of these, bronze was used for making the smaller denominations. The widow's mite described in the Bible was a tiny bronze coin, smaller than our penny, minted in Palestine.

The coinage of all civilized peoples from Bible times to the present has included bronze or brass coins. The "coppers" of Benjamin Franklin's time were much larger than our present-day pennies. They were, in fact, almost as large as half-dollars. If his friends loaded his pockets very heavily with these coins, as suggested in the quotation at the head of this chapter, his pockets must indeed have sagged.

Pennies are not the only modern coins that contain copper. Nickels are really two-thirds copper and only one-third nickel. Dimes, quarters, half dollars, and silver dollars consist of an alloy of silver with about one-tenth copper, the copper being added to make them harder and better able to stand the wear and tear of handling. Gold coins contain a small amount of copper, added for the same purpose. Thus every single coin that we have contains copper in a larger or smaller amount.

Coins nowadays are not stamped to show the exact weight of the metal in them. Weights of a pound, or even an ounce, would be unhandy to carry around. For this reason, coins of a convenient size have been adopted, and are stamped with names instead of weights, each coin bearing a certain relation in value to the dollar.

BELLS AND WATCH CASES

The characteristic of copper which recommends it for use in making coins is not so much its value as its durability. This same durability makes this metal useful for many purposes other than coinage. A watch case which is said to be eighteen carats solid gold really consists of eighteen twenty-fourths gold and six twenty-fourths copper. This alliance of gold and copper results in a product that is harder than either pure gold

or copper alone. Solid gold and silver articles, including jewelry, tableware, fountain pen points, medals, and watch cases, are without exception alloys—gold and silver to which a small amount of copper is added to make the more precious metals harder.

Bells which have been rung faithfully for many centuries, and which will continue to give service for future generations, are made of a so-called bell metal, which is an alloy of copper and tin.

COPPER IN CONSTRUCTION WORK

The durability of copper also makes it valuable for construction work of many kinds. For out-of-door use there is no metal that can stand the action of the weather more successfully. When exposed to the weather for any length of time, copper becomes coated with a thin green film of verdigris, a compound of copper with carbon, hydrogen, and oxygen. This film sticks to the metal so tightly that the metal itself is protected for centuries against further action of the weather. In this respect copper is superior to iron, since iron rusts in the air, forming rust scales which peel off and thus permit more and more of the metal to be acted upon.

Because of its ability to withstand the action of the weather, copper is valuable as a roofing material. Many skyscrapers, churches, and public buildings are roofed with this metal. The tower of the Woolworth Building is capped with copper, and the ornamental work adorning its cornices is etched with "gold" leaf. The so-called gold leaf used in this case is really brass leaf, which is made of brass hammered into sheets as thin as tissue paper, with a color and luster similar to that of gold. In addition to this exterior use of copper, the Woolworth Building is brass-equipped throughout its water system. Brass is especially valuable for holding and conveying water, since it is not subject to rusting, as is iron. In the construction of the water system of this building, 180,000 pounds of brass were

From a pencil drawing by E. Horter
Courtesy Joseph Dixon Crucible Co.

THE WOOLWORTH BUILDING

The tower of the Woolworth Building is capped with copper, and the ornamental work adorning its cornices is etched with brass leaf. In the water system of this building there are 180,000 pounds of brass, and in its elevator system 875 miles of copper wire.

used. In addition to this, the elevator system of the building required 875 miles of copper wire for its installation.

In our own homes we will probably find copper used in quite as many ways as in the Woolworth Building, although not in such startling amounts. The gutters and leaders which drain our roofs may be of this metal. Our windows may be equipped with bronze weather strips as a protection against the cold winds of winter. The screens used on our house in summer as a protection against insects are probably of bronze. The sash chains which permit the raising and lowering of the windows are probably of bronze links. Brass handles and locks are likely to be found on our doors. The doors probably swing back and forth on brass hinges. A brass knocker may be used on our entrance doors.

COPPER AND AUTOMOBILES

The durability of copper makes it a valuable material in the construction of an automobile. In many parts of the car it is absolutely necessary, and in many others it serves better than any other metal. Thus all the wiring for lighting, starting, and ignition is of copper. All the priming cocks are of brass, because it does not corrode. The carbureter and the vacuum tank are of brass, the gasoline piping is of copper, and the water pump is of bronze, since metals which will not corrode are needed for these parts.

There are many other places in which copper or one of its alloys give better results than would be secured with other metals. Thus nickel-plated brass is superior for radiator shells, door handles, lamps and gear shift and emergency brake levers, because of its non-corrosive qualities. A copper gasoline tank will not corrode, and is therefore unlikely to develop leaks. Brass hinges for the hood give better satisfaction than those of iron, and brass windshield frames do not rust or squeak.

In all, there are about 45 pounds of copper in the average passenger automobile.

COPPER AND ELECTRICITY

Besides serving in the actual construction of many articles of great importance, copper plays an important part in this modern electrical age of ours. Because copper conducts the

COPPER WIRES FANNED INTO A CABLE

electric current better than any other metal of reasonable price, it is used for telephone, telegraph, and power transmission lines. Cables consisting of a number of paper-insulated copper wires surrounded by a lead sheath furnish

the means of transmitting messages from one part of the country to another, and from one continent to another. The fact that New York City alone requires 5,000,000 miles of copper wire for its telephone system gives us but a tiny hint of the enormous amount of wire required in all the cities of the world, to say nothing of that needed to join the cities together.

Power, which may be generated either by dynamos having many important copper parts or by huge bronze turbines churning in tumbling waters, is now transmitted long distances over copper wires. One of the lines carrying the highest voltage ever used in electrical transmission is that owned by the Southern California Edison Company. This line carries 220,000 volts. Ten million pounds of copper were required to build it.

COPPER AND NICKEL GET TOGETHER

Copper, a metal ranking next to gold in antiquity, has recently been alloyed with nickel, discovered in 1751, in the production of an extraordinarily important alloy called Monel metal. The metal consists of 67 per cent nickel, 28 per cent copper, and 5 per cent manganese and iron. It is made by a recently perfected method of smelting nickel and copper ores together.

Monel metal is remarkable for its tensile strength, hardness, and resistance to acids. It is an invention of the International Nickel Company, and is named after the president of the organization. Besides having an extensive use in industries where acid solutions are handled, this alloy is used to make equipment for hotel kitchens; lamp brackets, fenders, and other metallic parts of motor cars; valves, bolts, and nuts; corners and fittings for trucks; screens used for the artificial propagation of oysters; and for a long list of things almost unbelievable in its variety.

COPPER COMPOUNDS

Whether copper is used for making cooking utensils, coins, parts of buildings, or electrical cables, the metal has to be separated by man from one of the copper-containing ores found in nature, since only small amounts of the metal are found uncombined. The ores of copper are almost all characteristically blue or greenish-blue. Perhaps some of us have never seen a specimen of azurite, malachite, or any of the common copper ores. There is surely no one, however, who has never seen at least one of copper's most important compounds, namely, blue vitriol or crystalline copper sulphate.

Blue vitriol is very widely known because of its use in batteries. One other important use of this compound is in the making of Bordeaux mixture, a preparation for preventing the growth of mildew and other fungi on plants. The following story is told of the way in which Bordeaux mixture came into common use:

During the nineteenth century, the vineyard owners near Medoe, France, began the practice of pouring a mixture of blue vitriol solution and lime over their grapevines. The purpose of applying this preparation was to prevent boys from stealing grapes. When the mixture dried on the vines, the grapes took on a decidedly poisonous appearance. In 1882 a professor of botany by the name of Millardet, at the University of Bordeaux, visited these vineyards. He was told by the proprietors that the parts of the vineyard that had been treated to frighten off bad boys were no longer infested with mildew. Professor Millardet thereupon went back to his laboratory and ran tests in order to check up on the report of the vineyard owners. When he found that this mixture really acted as a fungicide, he published the results, and the copper-sulphate-lime preparation, under the name of Bordeaux Mixture, came to be commonly used for spraying.

A COPPER BONANZA

Blue vitriol is not found in beds of ore, but is a manufactured product. This compound does not occur as an ore because it is soluble in water and would be washed away from any natural deposit. The ores of copper which Mother Nature supplies are all insoluble compounds of this metal, tucked away sometimes deep underneath the earth, and sometimes so near the surface that they crop out of a hillside in plain view.

In one of the richest copper mines ever discovered, the ore had been exposed to plain view perhaps from the very beginning of time. Nevertheless, it was not stumbled upon until 1898, probably because there were almost no people in the region to find it. This was the Bonanza Mine in Alaska. Its story is an interesting one.

In 1898 a party of men were prospecting in Alaska. Two members of the party, Jack Smith and Clarence Werner, were sent to seek pasture for the horses. They were near the headwater of a river when they noticed high up on a hillside a stretch that was bluish-green in color. They thought that it was a promising pasture strip, so they proceeded leisurely in its direction. When they were part way up and sat down to rest for a few minutes, one of them picked up a piece of bluish-green rock which was lying on the ground. He thought that it might be an ore of some kind, and put it in his pocket.

Later, when the two men reached the "pasture," they found that it consisted of a great mass of brightly colored rock cropping out from the hillside. They thought that the rocks might consist of copper ore, and later tests proved that they were right.

Many prospectors had seen this "pasture" previously, for this stretch of land was in full view of all those who had gone up the valley to the Klondike region during the gold rush. If any of these previous passers-by had chanced to pick up a

A MEDIEVAL MINE

(From a woodcut in Agricola, *De Re Metallica.*)

stray piece of the greenish-blue ore, he probably threw it away at once as of no value, since gold was the only thing that people were interested in at that time.

Even after Smith, Werner, and other members of their party staked out claims, no great amount of interest was aroused in their copper mine. Even these men did not realize the value

A MODERN MINE

Exterior view of a mine of the Utah Copper Company.

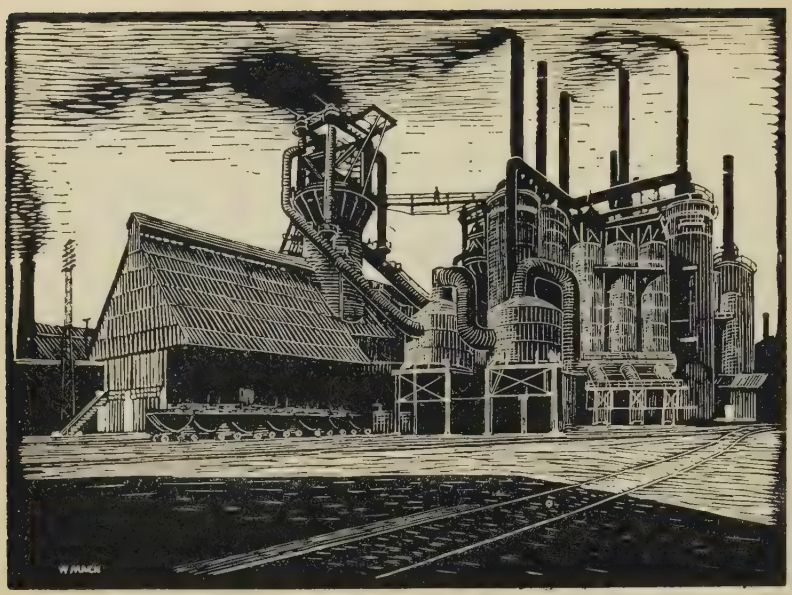
of their find, and they considered themselves more than lucky to sell their holdings at what they thought to be a wonderful price. Stephen Birch, a man who had a great deal of faith in the future possibilities of the mine, bought up the claims of all of the prospectors for about $7,000,000.

When Birch began to operate the Bonanza Mine, it was found that the ore yielded seven-tenths copper, and that it cost

very little to dig it out. From the opening of the mine to the present time it has yielded enormous quantities of ore. The ore is hauled to a town in Alaska called Cordova, and shipped by boat from there to the State of Washington to be smelted. Several million tons of ore are dug out each week. During one week in 1916, six shiploads left Cordova with a total amount of ore worth $7,200,000. This sum was slightly more than that originally paid for the whole hillside "pasture" tract.

Several million dollars for a week's shipment of copper ore from one mine can give but a small idea of the importance of copper in the world's industry. No hard and fast figures, however, could ever truly represent the important part this metal has to play in our everyday lives. At the present time, the United States leads all other nations of the world in copper production. More than half the copper ore mined in the entire world is produced here. We use in this country almost all of the copper that we mine. The greatest amount is used for making electric wiring and equipment. Next in quantity is the amount used in the construction of buildings. The quantity is further boosted by the amount used in making ships, railroad equipment, and automobiles, to say nothing of cauldrons, coins, and an unbelievable number of other articles.

Copper has come to be a metal by which our material progress can be judged, both by its direct use in practically every industry, and also by helping, as a part of our coinage, to represent the value of everything else that we produce.



BLAST FURNACES

CHAPTER XIV

SKILLETS AND SKYSCRAPERS

Then at length the doughty wanderer
Saw the beauteous dale before him.
When he entered on the valley,
While yet distant, to his ears
Came the roar of bellows blowing,
And the beat of hammers striking,
As, to time, they smote the anvil.

—LONGFELLOW

IN Homer's *Iliad* there is the story of a Grecian athletic contest held on the plains outside the city of Troy. This city was being besieged by the Greeks at the time, but fighting had been suspended for the moment while the Grecian warriors took part in the funeral games commemorating the death of one of their number. The first event was a chariot race in which various soldiers drove their shiny bronze and tin war chariots across the plain. This was followed by a

boxing match, a wrestling bout, and contests in archery and spear throwing. Not least among the events was the weight throwing contest, in which a lump of unwrought iron, just as it came from the furnace, was hurled by the contestants. This rough mass of iron served not only as the weight, but also as the prize.

In those days iron was a rare metal in Greece; but that was about one thousand years before the birth of Christ, when iron had been known in that country but a short time. Bronze and tin were the only metals used by the Greeks for making articles of everyday need, for iron was still so new and rare that its chief use was for finger rings and ornaments.

The people of Palestine, who lived but a short distance from Greece as distances are counted to-day, at that time had begun to use iron on a large scale. We find from the Bible that they had begun to make such articles as axes, plowshares, chariots, knives, swords, forks, picks, and spears.

There was a time, however, when the Israelites and their close neighbors had likewise considered iron to be a precious metal. When the Israelites made their exodus from Egypt, they were not acquainted with this metal, for the Egyptians did not use it in any quantity. When, after their forty years of wandering, they finally reached the promised land, they found the people of Canaan using iron for various purposes. Joshua considered this metal to be so valuable that he ordered the iron goblets of the Canaanites to be seized and placed in the Tabernacle along with those of gold, silver, and brass.

A VALUABLE IRON BED

A little later the Israelites went out to fight Og, the king of Bashan. When they had killed the king and completely overcome his army, they loaded up his most valuable possessions and carried them off as trophies. Among the most treasured of these was an iron bed of state in which the king had slept.

Now Og was "the last of a race of giants," and his bed measured sixteen and one-half feet long and seven and one-third feet wide. In spite of its bulk, the men of the Israelite army were willing to be burdened with it because of its great value.

When the people of Palestine learned how to produce iron in large quantities, they no longer counted it as a precious metal. Instead, it took its place as the leading metal of general utility. The method of producing and using iron thereupon spread from this region to other countries bordering on the Mediterranean.

IRON COINS UNWIELDY

During the time of Lycurgus, the lawgiver of Sparta, about the ninth century B.C., iron had become very cheap in Greece. The Greeks had come by this time to use it for making utensils, swords, spears, shields, and farming implements. Lycurgus used iron even for coinage, but not because he considered it a precious metal. His purpose was rather to cure his people of greed. He commanded that all gold and silver coins be called in, and that only iron money be circulated. Iron had become so cheap by this time that a cart drawn by two oxen was needed to carry home a sum of ten minæ, equal in our money to $88.80. An entire room was likewise needed in which to store this sum. Lycurgus' plan had the desired result on the Spartans, for few of them had sufficient house room to permit them to hoard any great sum of money, and no one was tempted to break in and steal coins of such size. In the long run, however, the scheme did not work out because trade with foreign countries was thereby almost impossible.

It seems to us almost beyond belief that iron could ever have been considered a rare and precious metal. It seems even more incredible that the most ancient inhabitants of this earth knew nothing at all about it. Although iron makes up about five per cent of the earth's crust, early man lived through an

ironless age lasting for thousands of years because he did not know that it existed, much less how to extract it from its ores. Then some one, perhaps an inhabitant of Canaan or one of the neighboring countries, finally stumbled upon the secret of iron's existence when he accidentally smelted a piece of iron ore in a wood fire. The news of the discovery traveled only by slow and tedious stages, not reaching even nearby countries for hundreds of years. Meanwhile, some other parts of the world also had probably stumbled upon the same secret.

THE MIGHTY SMITH

There is no calling of man around which more romantic stories have been woven than that of the master smith. In the Bible, Genesis 1:4, 22, Tubal Cain was described as a master in all kinds of bronze and iron work.

In Greek mythology, Olympus is provided with metal works of art, including iron, by the artificer Hephæstus. The Latin King of the Gods secured not only his metal art objects, but also his weapons, from the greatest of all mythological smiths —Vulcan.

Even before the art of sewing hides—to make bellows—was understood, some early peoples fanned the smelting ore with the wings of large birds. This is mentioned in the *Rigveda*, as follows:

> The smith with brushwood on the hearth,
> And in his hand a goose's wing
> With anvil and a blazing fire,
> Awaits a wealthy customer.

Some smiths of the early Middle Ages were attached to wealthy estates. In such connections the master usually established the smith's workshop in the most sequestered forest on his land. This was done both as a means of protecting his supply of weapons in case of a conflict with a neighboring titleholder, and of keeping his own military preparations a secret.

This practice led to a feeling of a certain mysticism surrounding the doings of smiths. Smiths sometimes were even classed as sorcerers. Thus, in Ireland, St. Patrick, the patron saint, invokes protection against the incantations of women, smiths, and Druids.

Not only was magic ascribed to many early smiths, but many virtues other than iron-working were frequently attributed to them. Medicine, music, poetry, and the dance were thought to be arts which a man so skilled as to make a gleaming sword from a lump of useless ore must certainly possess. The high esteem in which smiths were held in the Middle Ages is evidenced by the fact that King Geiserich of Germany once elevated a smith to the rank of a count. The killing of a smith in many medieval codes of law was punished by a heavier penalty than that for the killing of other vassals.

ANCIENT SMELTING

The ancient method of smelting iron was very simple. Iron ore was mixed with wood charcoal and heated in a good draft of air. The other elements in the ore with which the iron was combined were induced by the heat of the fire to part company with the iron and to join with the charcoal and the oxygen of the air. The molten iron was then drawn off and cooled. The metal was heated and hammered by turns until it was fashioned into the desired article.

In some of the primitive tribes of Africa, the ancient method of separating iron from its ores is still followed. The smelting is done in a crude clay furnace about 5 feet high and 2 to 3 feet wide at the base. Into this furnace alternate layers of iron ore and wood charcoal are placed. Four holes at the bottom of the furnace permit air to be blown in by means of crude bellows. A hole is also provided for drawing off the melted iron, and another for the melted impurities or slag. These latter holes are kept plugged until the contents of the furnace

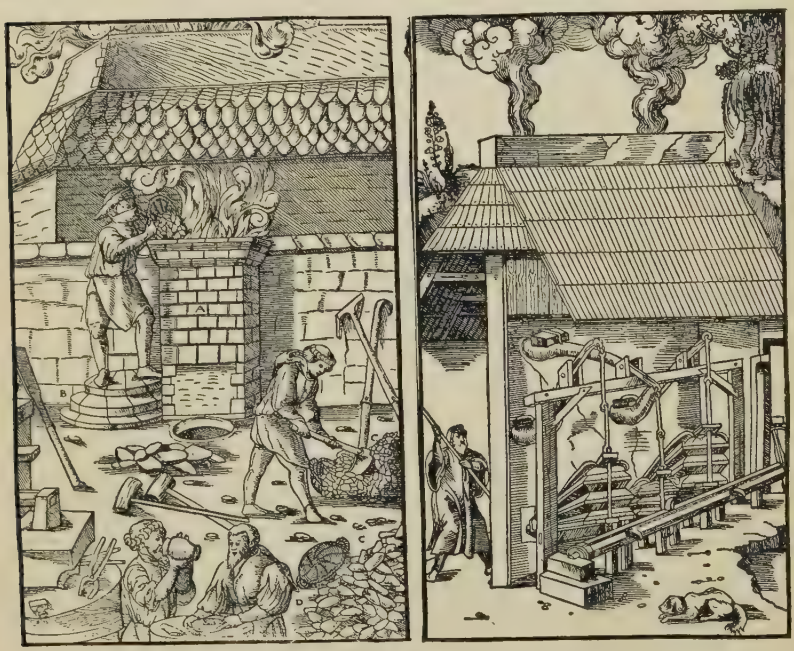
are melted. The molten mass, because of its greater weight, forms a layer at the bottom of the furnace. The impurities float on top. An opening at the top of the furnace serves as a chimney which allows the gaseous products to escape. This primitive African furnace is no doubt typical of that used by many ancient races.

FIFTEENTH CENTURY SMELTING

In Europe, the fifteenth century found but little change in the general method of smelting iron ore. The picture shown on the next page gives us some idea of the iron furnace of the Middle Ages. The furnace was somewhat larger, but the process was absolutely the same as that used in primitive times. In this picture the master of the iron works, who was quite an important person, is seen in the foreground. He is holding a mortar and pestle, a simple device used for grinding and crushing lumpy substances. He is ready to select a sample of ore from the pile and grind it up preparatory to testing its purity. The master's senior assistant is at this moment quenching his thirst from a water pitcher. This was quite necessary, since the heat from the furnace was very intense. The two apprentices are following their regular routine of adding ore and charcoal to the furnace. Because of the foul and choking gases which came from the smelting ore, these young men protect their lungs, as can be seen, by tying a bandage around their noses and mouths when they empty their baskets into the furnace.

The most noteworthy improvement which this furnace showed was in the construction of the bellows. The ancient hand bellows, itself a wonderful invention in its day, had been enlarged and improved prior to the fifteenth century until it had come to be quite complicated. The bellows used in the particular iron works shown here was not even operated by hand. It stood in a special room next to the furnace room, and

the nozzle opened through the wall into the lower part of the back of the furnace. Its form is shown in the accompanying picture, and its size can be somewhat appreciated when we see that it practically filled a large room. It was rigged up to a very complicated mechanical device which was operated by a water wheel. Thus waterpower had been made to take the place of hand power in this part of the smelting process.



IRON FURNACE OF THE MIDDLE AGES

Charging the furnace by hand (left), and supplying the molten mass with air by means of bellows driven by water power (right).

It would seem that the primitive furnace still used by some of the African tribes, and the somewhat improved furnace of Europe in the Middle Ages, could have no possible similarity to the modern gigantic blast furnace; but such is not true. The blast furnace differs from the earlier furnaces principally in size.

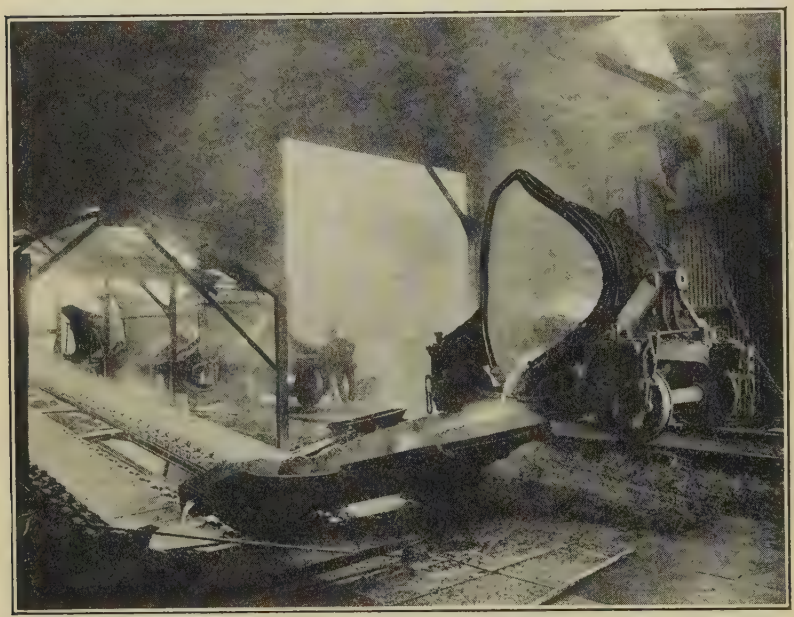
THE BLAST FURNACE

The modern blast furnace is 85 to 100 feet high. It consists of a steel shell lined with a special kind of fire brick. Instead of being filled with its charge by young men carrying small baskets, it is supplied with raw materials by small cars drawn up an inclined track by some mechanism which operates automatically.

In a blast furnace of the modern type, everything that is pitched into the top must come out a liquid. No unmelted lumps dare remain to shut off the draft or clog up the body of the furnace. Since clay, rock, and other substances which do not melt are naturally mixed with iron ore, they must be drawn out by some special process. It was found that lime will combine with these stubborn substances to form a material that melts quite easily. Therefore lime or limestone came to be added to the mixture in the furnace to act as a flux or substance which causes the clay and rock to melt in the extreme heat.

Another change that has been made in the smelting of iron ore is the substitution of coke for wood charcoal. During the latter part of the sixteenth century so much timber was being destroyed in England for making wood charcoal that Queen Elizabeth limited the amount of iron smelting that could be carried on. This proved to be quite a handicap to the iron smelters as well as to other workmen who needed this metal for various purposes. Inventors thereupon set about to hunt for a substitute for wood charcoal. Simon Sturvesant, and later Dud Dudley, found out that coal could be roasted until all the gaseous matter was driven off, leaving a residue of almost pure carbon. This residue, which they called coke, proved to be even more satisfactory than wood charcoal in the iron smelting industry. After this discovery, it was possible for the production of iron to be carried out on even a larger scale than was possible before the queen placed a restriction

on the industry, because coke proved to be cheaper and more generally satisfactory than charcoal. To-day, coke is still used in the blast furnaces instead of charcoal, because all the forests of the whole world could not yield enough charcoal to keep the furnaces of one plant running for a very long time.



Photograph by Chicago Architectural Photographing Co.

MAKING PIG IRON

Molten iron is run into molds where it hardens into "pigs."

In the modern blast furnace, neither the ancient hand bellows nor the improved medieval bellows operated by water power would be of any value in supplying air for so great a mass of melting ore. In fact, the size of the iron furnace has ever been limited by the amount of power available for forcing the current of air through it. After the perfection of the water power bellows, the iron furnace did not grow for many years because no one knew how to produce enough power to supply the air necessary for a larger device. In 1796, how-

ever, James Watt placed his steam engine on the market, and the problem was solved. Steam engines are now used in the iron industry to force mighty blasts of compressed air into the lower parts of the furnace at the rate of about 50,000 cubic feet per minute.

After the blast furnace has received its charge of ore, coke, and lime, and this mixture has been converted by the heat and air into layers of molten iron and slag, these materials are drawn off and fresh charges are constantly added. The molten iron is run into molds and allowed to harden into oblong blocks called "pig" iron or cast-iron. In some plants it is taken while still in a molten condition to another part of the plant, where it is dumped into a converter and changed into steel.

CAST-IRON

Cast-iron, or iron as it comes from the blast furnace, contains 4 to 5 per cent of carbon, together with a small amount of other impurities which have not been removed during the smelting. On account of its high content of carbon, it is quite hard and brittle and therefore easily broken. Cast-iron can therefore not be used by the blacksmith, because it would break if hammered on the anvil. It would also be of no value for making bridges or other articles which would have to bear great weights or stand sudden shocks.

Cast-iron, however, can be cast into molds because it has the particular virtue of expanding slightly when it solidifies from the molten condition. This causes it to force itself into the details of a mold.

In making articles of cast-iron, the metal is melted and poured into molds made of a particular sort of sand. These molds are prepared by pressing into the sand a model of the piece to be cast. Cast-iron is used for making stoves, radiators, pipes, and many other articles which demand hardness rather than particular strength.

WROUGHT IRON

Wrought iron may be made from cast-iron by taking out most of the carbon and other impurities. The cast-iron is heated in a special furnace with a small amount of iron oxide and suitable flux. The oxygen of the iron oxide unites with the carbon and other impurities, forming either gases which escape or liquids which separate with the slag.

Wrought iron is the purest commercial form of iron. It contains less than .3 per cent carbon, and as a result it has none of the brittleness of cast-iron. It is very tough and can be stretched and bent without breaking. Wrought iron is used by the blacksmith because it can be forged and welded. It serves to make articles intended to stand sudden and severe strains, such as anchors, chains, bolts, wire, and nails.

STEEL

Wrought iron is exceedingly tough and therefore has many important uses. It must, however, yield first place in importance to iron's chief alloy, steel. A large part of the iron taken from the blast furnace is converted into this alloy. Steel contains just the right amount of carbon to make it hard, but not enough to make it brittle. It can be tempered to a very high degree of hardness and can be made to take a very sharp edge. Steel can be made from cast-iron by burning out all of the carbon and other impurities from the cast-iron, and then adding exactly the right amount of carbon.

There are several methods of converting cast-iron into steel, each producing steel of a special quality. In the Bessemer process, fifteen to twenty tons of molten cast-iron are poured into a Bessemer converter, which is a gigantic pear-shaped furnace built of cast-iron plates and lined with a special heat-resisting preparation. Streams of compressed air are blown in through openings at the bottom of the converter. The air

oxidizes the carbon and other impurities, some of which escape as gases, while others separate as a light slag. So great an amount of heat is produced that dazzling flames and showers of sparks result.

At the proper time the air is turned off. When the blowing is stopped, minute particles of air become entrapped throughout the molten iron. If the iron were allowed to cool in this condition, it would be pitted. To prevent this, manganese is added. The manganese and the required amount of carbon are usually added in the form of "spiegeleisen," which is iron containing definite amounts of these elements. The manganese acts as sort of a scavenger. A part of it unites with the oxygen of the entrapped air and keeps the finished product from being porous. The compound of manganese and oxygen formed separates in the slag. The rest of the manganese forms an alloy with the iron and increases the hardness of the finished steel. Aluminum has to some extent come to replace manganese in steel-making.

The Bessemer process for converting cast-iron into steel requires only about thirty minutes. Bessemer steel is used for rails, axles, wire, and for structural purposes.

The most resistant steel is made by the Open Hearth process, in which pig iron is mixed with wrought iron or scrap steel and heated on a special hearth by means of an oxidizing gas flame. The gas acts both as a fuel and as an agent for oxidizing the impurities in the cast-iron. When the oxidation process has gone on until all of the impurities are removed, the correct amount of spiegeleisen is added. About eight to eleven hours are required for converting a charge of twenty tons by the Open Hearth process. This is consequently more expensive than the Bessemer process, but it produces a superior type of steel. Steel used for bridges, machinery, boilerplate, and large guns is made by the Open Hearth process.

Iron owes its high position among metals to a combination of characteristics not met with in any other material. It has

nearly twice as great strength or tenacity as copper, the next strongest metal. In spite of its strength, it is quite light of weight.

Iron is one of the most rigid and unyielding of metals and can therefore be depended upon to give a trustworthy support to other materials. In spite of its rigidity, however, it can be rolled into thin sheets and drawn into fine wires. An iron wire one-tenth inch in diameter can hold a weight of 705 pounds, while a copper wire of the same size can hold a weight of only 385 pounds.

Although pure iron has the greatest strength of any of the metals, steel has strength that is about one-third greater than that of iron. The strength of this material can be appreciated when we consider the great strain placed upon the structural framework of a skyscraper of thirty to fifty stories in height. Bridges made of steel give further evidence of the strength of this material. Hell Gate Bridge, New York City, one of the longest bridges in the world, is made of steel arches. In addition to supporting its own weight of 28,000 tons, it was made strong enough to stand the weight of forty-eight of the heaviest locomotives.

BROOKLYN BRIDGE

Brooklyn Bridge, one of the first splendid suspension bridges in the world, is held in place by cables of steel wire. This bridge consists of a platform hung from four parallel cables. These cables pass over towers and have their ends fastened in firm anchorages. Each of the four main cables consists of 5,296 steel wires bound together in a solid mass, each 16 inches in diameter. The main cables are assisted by shorter cables also made of steel wire. It is estimated that no less than a million people, some on foot and some in street cars and automobiles, as well as hundreds of vehicles pass over Brooklyn Bridge each day and trust their safety to steel wires.

Photograph by Wide World Photos

BROOKLYN BRIDGE

Cables of steel wire support this span over which pass more than a million persons a day.

TEMPERING

Steel can be tempered until it is almost unbelievably hard. Some primitive blacksmith who plunged a red hot bar of crude steel into water to cool it was the first to notice that this treatment made the metal harder. Unfortunately the name of the inventor was not recorded, and we cannot pay him the honor which is his due. This was the beginning of the tempering of steel. Later it was found that oil served better than water, and that almost any degree of hardness could be obtained by regulating the amount of heat applied and the rate of cooling.

COMPETITION IN THE STRENGTH OF STUFF

Competition in the tempering of steel, so that the product may be able to cut or pierce the best known steel, has been going on since the discovery of the tempering process. The old Nibelungen myths relate how one smith made a suit of armor that would withstand the attack of any sword in existence. A second smith thereupon produced a sword with which he cut in two both the suit of armor and the first smith, who was foolhardy enough to wear it in the demonstration. Siegfried, one of the heroes of the Nibelungen myths, when he had finished tempering the sword Notung, cut in two the anvil on which he forged it.

Nowadays our munition plants duplicate the rivalry of these ancient smiths in producing, first an armor plate that will resist all projectiles, and then a projectile with a point of such hardness that it will pierce the newly perfected handiwork of the armor plate manufacturer.

ALLOYS OF STEEL

Besides having a wide range of possible uses because it can be tempered, steel likewise forms many important alloys which

further extend its importance. Thus, if 12 to 14 per cent more manganese than is used in ordinary steel is added, an especially hard and tough product suitable for making grinding machinery and burglar-proof safes is produced. If tungsten is alloyed with steel, the product does not need to be plunged into water or oil to temper it, because it is self-hardening. Tungsten steel also keeps its temper, even when it becomes quite hot, which is not true with ordinary steel. It can thus be used for making the cutting edges of high-speed lathes and other machinery of that sort. At the present time, one man with a lathe with tungsten steel tools can do the work formerly done by five men with five lathes fitted with ordinary steel cutting-edges.

These are but a few of the important and interesting alloy steels which can be made to have almost any degree of hardness, brittleness, toughness, elasticity, rigidity, or strength.

CORROSION

While considering the qualities which make iron the most important of all the metals, however, it is no more than fair to recognize its one great fault—its tendency to rust. If a piece of iron is heated and hung in a jar of oxygen, it will burn with quite a display of fireworks. The ash that is left after the burning is a compound of iron and oxygen, commonly called rust. If iron is exposed to the weather for any length of time, it will rust just as if it were burned in a jar of oxygen, only the process is much slower, and not enough heat is formed at one time to cause the sparks to fly. Except for the time required, however, the burning of iron in oxygen and the rusting of iron in air are similar processes.

An unbelievable amount of iron is lost each year by rusting. This amount in fact exceeds that lost by fire. At this rate, a considerable quantity of iron produced each year in this country goes for replacing iron that has been lost by rusting. To save a pound of metallic iron from rusting, therefore, is just

as important as to extract a pound of this metal from its ores, which are chiefly nothing more than iron rust. In fact, the former is even more important, because coke is not required to save the iron from rusting. It does, on the other hand, require four times as much coal to make coke as the amount of iron produced by the use of this coke.

One means of protecting iron from the corroding influences of the weather is to coat it with some substance that is less easily affected by air and moisture. Structural steel is painted for this very purpose. One of the most common paints used for the protection of structural steel is a brilliant orange red in color, which contains red lead (a compound of lead and oxygen). Another common paint used for this purpose contains iron rust itself as the pigment. This iron rust held firmly to the surface of the steel by linseed oil acts as a safeguard against corrosion of the steel.

A common method of shielding iron from the invasions of air and moisture is to coat it with another metal which is not easily corroded. Depositing a layer of nickel on the surface of iron by electricity is an excellent method of protecting it. Nickel-plated iron cannot be used except for small objects, however, because of the cost of nickel.

If iron is dipped in melted tin, it becomes coated with a thin smooth layer of this non-corrosive metal. Tinned iron is very satisfactory for making pails, cups, cans, and sheet metal. It wears quite well until the outer layer of tin is scratched; then the iron rusts even more rapidly than if it were not coated, because an electrolytic action is set up between the more electrically active iron and the less active tin.

Galvanized iron, or iron covered with a layer of zinc, is more durable than tinned iron. The conditions here are the opposite of those in the case of tin and iron. Zinc is electrically more active than iron and will corrode to the last speck before the iron begins to rust. Galvanized iron therefore is quite durable and is used for making tanks, tubs,

buckets, roofing material, drain pipe, and corrugated sheet metal.

In the struggle against rust, more important progress has been made than in the mere coating of the metal with an outside protective layer. A number of plants have found that iron which contains impurities rusts very much more rapidly than pure iron. As a result of this discovery, they manufacture an exceedingly pure form of iron which shows superior durability when exposed to air. Scientists have also found that steel can be made to withstand rust by alloying it with certain other metals. An alloy steel containing about 15 per cent of silicon and called by such names as duriron, tantiron, or ironac is not only rust-proof, but acid-proof as well. An alloy of steel with the metal chromium is likewise rust-proof and acid-proof and is used to make the stainless steel knife blades so popular in the dining room and kitchen.

And so man's problem with iron has been not only to learn how to separate it from the ores supplied by nature, and to harden and toughen it to his needs, but also to keep it from rusting and thus going back to the form in which he first found it. The race with rust goes on each year, but each year man extracts more iron from its ores, and each year he thinks of new ways of slowing up its rate of rusting.

The increase in the rate of producing iron during the last fifty years has been amazing. In fact, the annual production in the United States during that period has been multiplied seventeen times over.

The abundance of iron, its cheapness, its superior strength, and the wide variety of uses for which it alone is applicable make it man's most important material. No other metal has such a range of degrees of elasticity that it can be used for the most delicate of watch springs and also for the strongest of trusses under railroad coaches. No other metal can be alloyed and tempered until it can take the finest edges demanded by a safety razor blade, as well as the durable edge

needed by high-speed cutting machinery. Iron is the only metal which could have the wide variety of uses ranging from the making of such modest household articles as carpet tacks to the construction of giant suspension bridges, or from the making of skillets to the manufacture of the structural framework of massive skyscrapers.

Courtesy International Silver Co.

MODERN REPRODUCTIONS OF COLONIAL PEWTER

The everyday pewter of Colonial days has become the exclusive ware of modern times. This collection contains reproductions of Colonial, English, and Fleming ware of two or more centuries ago.

CHAPTER XV

SOLDER AND PEWTER

We caused a skilful Pewterer . . . to close it up . . . with soder.
—BOYLE, 1660

Her pewther glanc'd upo' your een Like siller plate.
—RAMSAY, 1717

THERE are two metals, known since ancient times, which are among man's most important materials. These are tin and lead. They were not distinguished from one another in early times, but were thought to be different varieties of the same metal. Tin was called *plumbum candidum,* or "the white variety of lead," while lead was called

plumbum nigrum, or "black lead." Basil Valentine, a monk, showed for the first time in 1450 A.D. that these were distinct metals.

Although lead and tin have long since been shown to be different substances, they are still used together in a number of alloys. Chief of these are solder and pewter.

ANTIQUITY OF LEAD

Lead was known in ancient times, although it never rivaled copper or iron in the amounts used in early Egypt and Asia Minor. The antiquity of this metal is testified to by the fact that a leaden figure dating from 3800 B.C. was found in one of the ancient Egyptian tombs. This figure is now on exhibit in the British Museum. Other leaden articles likewise have been found to date from ancient times, although it was not used as much as some of the other metals, such as copper and gold.

Lead was known in Moses' time. When this great prophet sang his song of praise to Jehovah for having permitted the Israelites to pass safely over the Red Sea, he describes in Exodus 15: 10, the drowning of the Egyptians as follows: "Thou didst blow with thy wind, the sea covered them; they sank as lead in the mighty waters."

The Assyrians used lead 3,000 years ago to fix iron clamps in stone bridges. The ancient Greeks knew and used lead, as is shown by the number of leaden articles that have been found in the ruins of ancient Troy.

The Romans used lead on a larger scale than any of the earlier civilizations. They employed this metal extensively for making water pipes. They also had a lead-tin solder not much different in composition from that in use to-day. Wherever a victorious Roman army went, they carried the use of lead in plumbing with them. The mines of Spain and Britain supplied them with lead ore.

FISHLINE SINKERS AND PLUMB LINES

One of the characteristics of lead which first recommended it to ancient peoples was its weight. As early as 1200 B.C., lead was used by the Egyptians as sinkers on fishing nets. Lead is the heaviest of the common metals, being eleven times as heavy as water. To be sure, osmium, an exceedingly rare metal discovered only recently, is the heaviest of the metals, since it is twenty-two times as heavy as water and thus twice as heavy as lead. Gold and platinum are also heavier than lead. Ancient fishermen, however, did not know osmium or platinum, and none of the ancients (unless King Crœsus or King Midas went in for fishing) would have thought of using gold sinkers, since the less expensive lead served quite as well.

From ancient until modern times lead held first place as the metal used where compact weight coupled with non-corrosibility is desired. In addition to fishline and fish-net sinkers, it is sometimes used to-day to cover the shanks of fishhooks and to sheathe decoy minnows used to lure fish to the hook. In carpentry, a weight of lead hung on a cord is used to get a wall straight up and down. Lead is also used as clock weights, as window-sash weights, and as weights to hold down the tails of people's coats.

Lead is likewise used in exploring the depth of the ocean. When a ship is in a fog or in strange waters, the depth of the water is determined by sinking a line, on the end of which is a cylindrical piece of lead. The depth to which the lead sinks before it reaches the bottom is automatically recorded. This practice is called "sounding" the depth of the water. The nature of the bottom of the ocean in a certain place may be determined at the same time by putting tallow on the bottom of the sounding lead. When the line is drawn up, the particles adhering to the tallow give an indication of the type of bottom which lies underneath.

When deep-sea divers go under the water to explore the floor

of the ocean, to seek for treasure of one sort or another, or to engage in under-water construction work, their suits and shoes are weighted with lead to keep them down. The keels of racing yachts are weighted with lead because a small amount of this metal will supply as much weight as a larger amount of other metals.

The weights of some scales are first made of iron, lighter than desired. They are then brought up to the desired weight by pouring melted lead into a depression or by loading the weight with lead shot and sealing it.

SHOT AND BULLETS

Lead is used in making shot and bullets, because in these articles weight is necessary in order to insure the required momentum.

In making shot, the lead is alloyed with a small amount of arsenic. The arsenic hardens the lead and also lowers its melting point. The melted alloy of lead and arsenic is dropped through a perforated strainer and allowed to fall a considerable distance into water. The small amount of arsenic makes the lead more fluid and thus prevents the droplets from hardening until they become spherical. The hardened spheres are assorted as to size by causing them to run down inclined planes over screens of different sized meshes. The smallest shot fall through the first smaller openings into the collecting bins. The larger ones roll on to the larger holes. Irregular pieces do not roll well and are finally pushed off at the end of the incline.

Bullets used for pistols, rifles, and machine guns are made of lead. The latter two types are sometimes tipped with steel. Shrapnel shells are also filled with lead balls.

PLUMBERS, PLUMBING, AND PLUMBISM

The plumber was originally a man who worked exclusively with lead. The word plumber comes from *plumbum,* the old

Latin word for lead. The chemist's symbol for lead, *Pb*, comes from the Latin name for the element. A plumber therefore is a worker in lead. A plumb line is a line weighted at the end with a plummet or a piece of lead. The expression "he falls plumb down" really means that he falls down like a lump of lead.

The plumber of to-day is the workman who installs and repairs the water systems in our houses, regardless of whether he puts in pipes of lead or of other metals. Because lead can be easily cut, bent, and adjusted to irregular shapes, and because it does not corrode, it is admirable for making water pipes.

When water (particularly soft water) stands in contact with lead for any length of time, however, the water reacts with the lead to form a lead compound which gets into the water. If water containing the smallest trace of lead is taken into the human system, no ill effects may be noted at first, but after repeatedly drinking water of this sort, enough lead will be stored up in the body to cause a serious disease called plumbism or lead poisoning. This results from the fact that lead is a cumulative poison, that is to say, it is not eliminated from the body; and small amounts taken at various times will accumulate until quite a bit is stored up. Because of the danger of using lead in any part of the water system where the water is likely to stand for any length of time, iron and brass have supplanted the use of lead in plumbing. For drain pipes, however, lead is still used to some extent because the extreme smoothness of the interior prevents the accumulation of solid material.

SOLDER

One of the plumber's chief materials is solder. A solder, according to the dictionary, is a material used to consolidate or to make solid. Ordinary solder is an alloy of lead and tin used to seal pipes together and to stop leaks. The particular

virtue of solder is that it melts at a lower temperature than does either tin or lead used alone.

	Melting Point	
	Fahrenheit	Centigrade
Lead	620°	316°
Tin	450°	232°
Solder	358°	181°

A solder of tin alone could not be used to join together pieces of tin or to mend leaks in tin, because the tin that was being joined or mended would melt at the same temperature as the solder. For the same reason a solder of pure lead would be valueless for joining or mending lead. A tin-lead alloy, however, having a lower melting temperature than either of the metals of which it is composed, can be applied in a molten condition either to tin or lead without causing them to melt.

Ordinary solder has a lower melting point than any of the common metals, and since it will adhere to most of them, except aluminum, the plumber finds it extremely valuable.

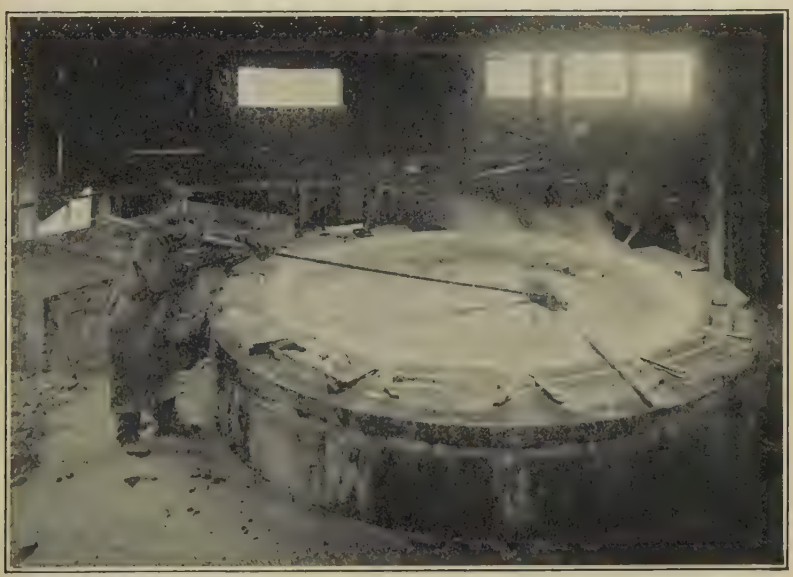
HOW MEN USE A SOFT METAL

Because lead is the softest of the metals in common use, it has many uses for which a harder metal would be of no value. The jeweler uses lead tools for much of his work, since hammers and mallets of lead do not bruise articles being fashioned from silver and gold. Because of the softness of this metal, jewelers also use anvils of lead and lead-lined vises.

Lead is used to make all sorts of things tight, because it is soft and easily hammered into crevices. When iron nails or bolts are driven into stone, concrete, or brick, the crevice around the piece of iron is so great that the nail or bolt is far from secure. Crevices of this sort may be calked up, and the iron made secure by hammering in shreds of metallic lead called "lead wool." The threads of the metal thus pack to-

gether into a solid, dense mass, and the iron bolt or nail is quite permanently fastened to its stone, concrete, or brick foundation.

The use of lead for calking is an exceedingly old practice. The Assyrians found difficulty 3,000 years ago in fastening iron bolts to a stone bridge. They solved their trouble by pouring molten lead around the bolt. The fastening of iron



Courtesy National Lead Co.

DESILVERIZING LEAD DURING THE REFINING PROCESS

to stone by means of melted lead is used even to-day. The axle of a grindstone is held firmly in the center of the stone by pouring melted lead around it. Melted lead is not as satisfactory as hammered lead wool, however, since the latter is better able to stand jars and vibrations without being loosened.

The softness of lead is further made use of in the so-called expansion bolt, one of the most important devices invented in modern times for securing objects to stone, concrete, or brick. It consists of an iron bolt upon which is placed a threaded

iron nut, conical in shape. The conical nut fits into a lead washer. A hole just large enough to admit the lead washer is drilled into the stone, concrete, or brick. The bolt is then forced into the hole. The hammering causes the iron nut to expand against the outer lead washer. This forces the lead against the sides of the hole and into every crevice, making an exceptionally firm anchorage. The thousands of seats in the famous Yale Bowl at New Haven are secured to the concrete terraced floor by means of iron-lead expansion bolts. Mooring posts on concrete piers, designed to stand the strain of ropes used to fasten ships to the pier, are held firm by this same device. Railroad tracks are likewise secured to concrete by expansion bolts which are made possible by the softness of lead.

LEAD IN ELECTRICAL DEVICES

Whenever you turn on the lights of your car or start the car's engine, or tune in on the radio, you are drawing upon electrical energy stored up in a so-called storage battery. Lead is the most important material used in the construction of the ordinary battery of this type. The plates of a storage battery are made of lead, with a small amount of antimony added to harden it. These plates are perforated, and two sets, usually of four or more plates each, are connected. The perforations of the plates of the first set are filled with a spongy mass of powdered lead. The perforations of the plates of the second set are filled with a paste of lead dioxide. These plates are placed in a hard-rubber container and immersed in a bath of sulphuric acid. When the battery is being discharged, there is a migration of electrically charged groups of atoms in a certain direction. Charging the battery consists of attaching it to a current which chases the groups of atoms back to their original plates.

Lead is used in many other electrical devices. Because of

its flexibility, resistance to moisture and air, this metal is used for sheathing electric cables. A lead-tin solder is used to fasten certain wires together. Lead compounds enter into the making of rubber used in insulating, and of glass used for making bulbs. Either lead or an alloy of lead is used to make the fuse wires that are inserted into the circuit that carries the electric current through our homes.

We are all familiar with the fuse plugs that are screwed into the circuit, usually at the switch, where the wiring enters a building. The fuse wire in one of these plugs, made of lead or a lead alloy, is deliberately made the weakest point in the circuit. When lightning strikes the electric system, or when a short circuit occurs, or when a great strain is placed on the line from any other cause, the fuse wire will be heated to its melting point in an instant. In this way it breaks the circuit and protects the electric lights from being burned out, and most likely prevents a fire from starting. In power plants, fuse plugs likewise act as safety valves, since they prevent an accidental overloading of the line with too strong a current from doing great damage to costly electrical equipment.

LEAD IN MUSICAL INSTRUMENTS

When we listen to the music of the pipe organ, we hear lead tell of another of its virtues. For lead is the most important material used in the making of the pipes of the organ. An alloy of lead, containing less than 1 per cent of other metals (added to harden it), is used for this purpose because of its almost complete lack of vibration and its superior tonal qualities.

Lead also has an important part to play in other musical instruments. The speed of the graphophone is regulated by governor balls of lead, and piano players contain tubing of lead, and lead in the keys.

Lead is the cheapest metal that can be used by manufactur-

ing plants to resist the action of certain acids. Chemical lead or lead containing just a trace of copper is used to construct acid chambers, pipes, and containers in plants where sulphuric acid is manufactured. In some concerns where certain acids are used, lead is necessary to make containers and pipes to convey corrosive liquids. Even the force pumps used in some chemical plants are lined with lead. Thus we see that this metal enters indirectly into the manufacture of many articles of which it is not itself a part.

FROM TOYS TO TORPEDOES

Toymakers use lead extensively, because it can be cast in a mold and thus be made to take any number of shapes. Toy soldiers and other figures of lead will not rust, and they may be painted in attractive colors. Miniature doll furniture is frequently made of lead, and the eyes of sleeping dolls are lead-weighted.

The collapsible tubes in which tooth pastes, face creams, shaving creams, library paste, glue, and other articles of common use are so conveniently put up are made of lead, covered outside and in with a thin coating of tin. The flexibility of lead makes it extremely valuable for this purpose.

When we look at the stained glass windows in churches, we see the flexibility of lead used in quite another way. The small strips of metal which join the pieces of colored glass, arranged to make a picture or conventional design, are of lead. No other material could be curved and bent to follow an elaborate outline.

Lead enters into the composition of many alloys besides those already mentioned. Alloys used to reduce friction, to fight fires, to make printer's type—all contain lead.

Lead is used for making seals. The gas and electric meters in our homes are locked with a piece of wire, and the ends of the wire are fastened together with a disc of lead bearing a

certain stamp. The presence of these seals prevents tampering with the meter. Cars loaded with express and freight are sealed in the same way. The breaking of a seal on a railroad car is a criminal offense.

Lead is important in the operation of torpedoes used to warn approaching trains of danger or to order them to stop. Safety torpedoes are attached to a lead bar about a foot long. The two end-pieces of the bar are fastened to the rail by being bent around it. When a train strikes the torpedo, there is a loud explosion.

LEAD IN GLASS, PORCELAIN, AND PAINTS

Lead compounds are ingredients of the finest kinds of glass. Glass is a mixture of the silicates of two or more metals. For making ordinary glass, sodium carbonate (ordinary washing soda), calcium carbonate, and fine white sand are heated together. These three products melt and react to form a mixture of sodium and calcium silicates, which, when hard, form the transparent substance we know as glass. To make better qualities of ordinary glass, a potassium compound is substituted for the soda. To make a very hard glass, a lead compound is substituted for the calcium carbonate. The lead compound most frequently used is lead monoxide, a compound of lead and oxygen.

The glazes on porcelain, pottery, chinaware, bathroom fixtures, and kitchen sinks are similar in composition to glass. White lead, the well-known white paint pigment, is a compound of lead, carbon, hydrogen, and oxygen, made by exposing lead buckles to moisture, vinegar fumes, and carbon dioxide for many weeks.

LEAD, THE PRECIOUS METAL

Orlando C. Harn, in the introduction to his book, *Lead, the Precious Metal*, records that the alchemists might have done

a real service to mankind if they had worked out some of the possible uses of lead, rather than to have spent their time in trying to change this metal to gold. He writes:

One might do worse in his search for entertainment than to delve into the daily life and activities of the metal lead. For, after all, the essence of entertainment is to run into the unexpected, to be surprised at every turn, to be suddenly introduced to something different from the humdrum experiences of our daily lives. The story of lead has all the elements of surprise and wonder. All the reader needs is a little imagination. One can then have a thrilling time exploring new worlds filled with constant marvels. One then also begins to appreciate things formerly little thought of, either because of their value measured not in commercial terms but by fundamental standards.

You doubtless recall Portia and her caskets three—one of "gaudy gold"; one of silver, the "pale and common drudge between man and man"; and a third of "meagre lead, which rather threatenest than dost promise aught." In one of them lay her portrait, and to him who guessed it she herself was pledged.

The Prince of Morocco and the Prince of Aragon, who in turn chose the golden and the silver caskets, believing that only one of these could be worthy to enshrine the portrait of this fair lady, were woefully lacking in imagination. They typified the unimaginative conventional masses who think in terms of gold and silver because these are the time-honored counters of wealth and the ornaments of our vanity.

Bassanio, who shrewdly guessed that in the forbidding leaden sheath lay the coveted token, was the forerunner of the practical scientist of to-day who values a thing for what he can make it do for mankind. To him lead is a precious metal just as truly as gold or silver. No matter if men give him a large lump of lead for a small lump of gold; that is a mere incident of the law of supply and demand and has naught to do with real value. He gladly exchanges the gold for the lead, if he has in mind to make a piece of glass or a storage-battery!

PEWTER

The antique-hunter purrs with pride over the finding of a pewter porridge bowl or tea pot—articles which in their own

day would have cost but a few cents and were used only as everyday ware, to save scratching the silver plate. To-day, a large part of the pewterware turned out by the manufacturers is fashioned after the same graceful designs of the ware common in America, England, and the Netherlands two centuries ago.

Courtesy International Silver Co.

THE ANCIENT ART OF THE PEWTERER

Pewter is an alloy of lead and tin, with a very small amount of antimony added to harden it. The members of the pewterers' guilds were bound by very strict regulations regarding the composition of the alloys which they were to use.

ANCIENT TIN

Tin, the other important ingredient of solder and pewter, was produced by the Phœnicians from the Cassiterides, writes Sydney Fawns in *Tin Deposits of the World*. Concerning this belief, he declares:

Although it seems pretty well established that the word *Cassiterides* comes from the Greek word for tin—*kassiteros*, the geographic location of the place is somewhat in doubt. The great weight of evidence compiled by the archæologists is, however, that this place corresponds to the Scilly and Channel Islands as well as to Cornwall [England], which is thought to have been detached from the mainland in ancient times. There is every indication that the Phœnicians not only secured tin from Cornwall and adjoining islands as early as 1200 B.C., but that they actually participated in the mining industry in this region themselves. It seems probable that for many centuries this maritime people maintained a monopoly in the tin industry by virtue of keeping the location of the mines a secret.

When the location of the Tin Islands became known to the outside world, the mines were worked by the Romans, the Greeks, and the Gauls at various times.

Cornwall was the most important source of tin until the thirteenth century. The main obstacle to the progress of deep mining in early times was underground streams of water which flooded the mines. Before the introduction of the steam engine, the water was raised by chain pumps and other crude mechanical devices, usually operated by horse power. With the invention of the steam engine by Watts, mining operations were materially assisted. The introduction of gunpowder for blasting in the Cornish mines during the eighteenth century also brought about an important advance in mining work.

The annual production of tin in Cornwall during the Middle Ages was as follows:

	Tons
13th century	300
14th to 16th century	500
17th century	1,200
18th century	2,600

TIN, THE PRECIOUS METAL

During the recent war, an article in the *Literary Digest* stated that tin was fast becoming a precious metal. This

Courtesy Philadelphia Commercial Museum

TIN CANS ARE MADE OF SHEET IRON COATED WITH TIN

The tin is deposited by dipping the iron plate into a vat of melted tin (above) and is made to adhere more firmly by running it under hot rollers (below).

statement was based on the price of tin, which in 1918 jumped from $50 a ton to $1 a pound for "Banca" (tin mined in the Island of Banca just off the coast of Java). The reason for this sudden rise was that only small amounts of tin reached America during the conflict.

Tin is needed in many alloys besides pewter and solder, such as bronze, bell-metal, gun metal, type metal, and Brittania metal. A tin shortage, therefore, is seriously felt in many industries. Tin was sold for 12.9 cents a pound in 1897; 27.23 cents in 1900; 30.5 cents in 1910; 39.97 cents in 1917, and 59.4 cents in April, 1918. The quotation of $1 a pound was made in September, 1918. The price has fluctuated seriously since that time, and has caused much distress to users of tin. The *Industrial Bulletin* issued by Arthur D. Little, Inc., states that man will have to find new deposits of tin or a suitable substitute for this metal, since the present supply is inadequate.

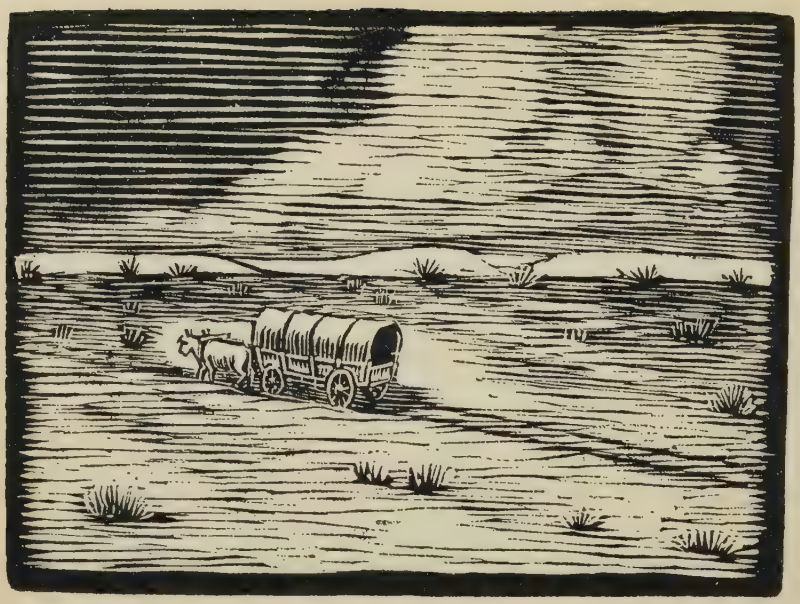
TIN CANS

Napoleon offered a prize of twelve thousand francs to the person who could invent a means of conserving food for the use of his armies. In 1814 Nicholas Appert won the prize. Appert, father of the canning industry, used glass containers, however, to preserve food.

About 1821 William Underwood, an Englishman, came to the United States and engaged in the shipping of fruits, jams, and jellies in glass containers. Shortly after this he began to use a "tin cannister" invented by Peter Durand, another Englishman. A master tinker in Underwood's time could turn out fifty to sixty cans a day. The tin can of to-day consists of iron, plated with tin. Tin-plated iron also serves in making many other articles of common use.

Lead and tin, the "black lead" and "white lead" of antiquity, from their earliest discovery, have been content to follow the rôle of metals of utility rather than of beauty. They

have come to be applied to so many important uses, nevertheless, that each has come to be called a precious metal. From fishline sinkers to glazes for beautiful pottery, lead has shown itself to be one of the most versatile of elements. And tin, its close relative and one of our most important plating materials, produces a non-corrodible layer on the surface of many articles, from tin cans to drain pipes, and serves also as an important ingredient of many everyday alloys.



THE FORTY-NINERS

"Why the crude bivouac? Why the gear of travelers? Why the massed arc-light of wagons?" (Emerson Hough, *The Covered Wagon*).

CHAPTER XVI

NOBLE STUFF

Dreams of Gold—
Scenes unfold—
Beauty,
Ease,
Change,
Music,
Warmth,
Friends.
—Nina Charlotte Martin

GOLD, silver, and platinum are quite unsociable metals. They take part in very few chemical reactions. Because they hold themselves aloof from the common run of chemical substances, they were called "noble metals" by the alchemists. The name has clung to them ever since.

GOLD

Gold, the yellow, lustrous bit of stuff which human beings crave, was probably the first metal to have been discovered by man. Because it is inactive chemically, it is found in a metallic state in nature. Hence it was an easy matter for early man to discover it, particularly since it occurs on the surface of the earth and in the beds of shallow streams in some places. All the names for gold in all languages mean "to glitter" or "to sparkle."

Because gold is soft, it can easily be wrought into various shapes suitable for jewelry; but it would not be adaptable for making tools, utensils, and weapons even if it were found in larger quantities than it is. For this reason, we find ancient man using this metal for making ornaments and coins, but not for making articles of everyday use.

At the time of King Snefru of Egypt and his son and daughter, Rahotep and Nefert (about 3500 B.C.), gold was not used extensively for ornamentation. By the time King Tutankh-amen reigned in all his glory—many centuries later—gold constituted the chief material for the ornamentation of royal personages. The lavish display of gold that was found in King Tutankh-amen's tomb is common knowledge. The Egyptians of his time worked extensively the gold mines of Nubia, which, in fact, were named after *nub,* the Egyptian word for gold.

COINS OF CRŒSUS

Crœsus, the wealthy ruler of Lydia of about 500 B.C., used gold not only for ornaments, but for coinage. Crœsus is believed to have been the first person to make gold coins anything like our modern pieces of money. Previous to this, gold was used as a medium of exchange either by weighing it on the scales at the time a purchase was made, or by having it cast into pieces with their weight stamped on them.

A few years ago, some of Crœsus' gold "staters" were unearthed. These coins were oval in shape, each weighing about a quarter of an ounce, and were rudely stamped on one side with the head of a lion and a bull. They were found in a small pot four and one-half inches high at what seemed to be the mouth of a tomb, by a group of American professors and a Turkish laborer who were exploring with pick and shovel for whatever relics of historical significance they could find. It was thought that the coins had been buried by some nervous Lydian at the time of a crisis, probably in 546 B.C., during the fourteen-day siege of their capital city by Cyrus of Persia. This, however is mere conjecture.

The fact that these recently discovered coins were made of an exceedingly pure gold, coupled with the fact that silver coins were also used in Crœsus' time, lead to the belief that the people of that time knew how to separate gold and silver from each other.

Many of the kings of ancient Lydia owned gold mines. Priam owned mines around Abydos; Midas owned mines in Mt. Bermius; Crœsus had extensive deposits, which he mined for gold, located between Altarnea and Pergamum.

THE MALLEABILITY AND DUCTILITY OF GOLD

The exceeding malleability of gold excited the admiration of the ancients and made it possible to gild objects by covering them with thin plates of the metal. Thus, many articles of furniture found in Tutankh-amen's tomb, as well as his throne and his human-shaped coffin, were covered with sheet gold.

One cubic foot of gold can be extended by the gold beater's hammer into leaves of sufficient size to cover a surface of one thousand square yards. Such a sheet would be 1/750 inch thick.

Gold is not only sufficiently malleable to be hammered into sheets, but its ductility enables it to be drawn into thin

wires. One ounce of gold can be drawn into upwards of 240 miles of wire.

HOW MANY CARATS FINE?

Pure gold is as soft as lead—too soft to be used for coinage, jewelry, or other objects of common usage. Alloyed with

WASHING GOLD IN THE MIDDLE AGES

The process was much the same as it was three hundred years later, when gold was discovered in California. To-day scientific methods have replaced the crude, hand-operated sieves. (Woodcut from Agricola, *De Re Metallica*, Book VIII.)

small amounts of copper, it becomes hard enough for all purposes.

The measurement of gold in carats refers to the number

of parts in 24 that is pure gold. An eighteen-carat ring or watch case is 18 parts gold alloyed with 6 parts copper.

SILVER

Silver is slightly more active chemically than gold, and hence not quite so "noble"—but almost.

The earliest known silver is thought to be a necklace owned

MOTION PICTURES IN THE ROUGH
Coating transparent films with an emulsion which is sensitive to light.

by an ancient Egyptian king of about 2400 B.C. Therefore it was undoubtedly not known at so early a date as was gold. From the Bible, it appears that silver was not known in Noah's time, although when Abraham lived it was quite common.

TABLE TOOLS AND MOVIES

At the present time, silver is used extensively not only for ornamentation and coinage—its earliest uses—but for making table silver and moving picture films.

The sensitive material on photographic and moving picture films consists of bromide, a compound of silver. Five million ounces of silver are used for this purpose each year in the United States alone. A number of plants in the country are engaged in the recovery of silver from waste liquors produced in the development of films.

BY-PRODUCT SILVER

About 70 per cent of the silver output is obtained by by-product treatment of ores of less valuable metals. The distribution is as follows: 30 per cent by the treatment of copper ores; 25 per cent by the treatment of lead ores; 15 per cent by the treatment of complex lead, zinc, and copper ores. The United States and Mexico produce about half of the world's supply of silver.

STERLING

Whereas the purity of gold is measured in carats, the degrees of purity of silver is measured in parts per thousand. (Silver, like gold, is too soft to be used without the addition of some other metal such as copper.)

The word *sterling* refers to a certain quality of silver, and means that an article is 925/1000 fine. That is to say, it consists of 925 parts silver and 75 parts some other metal (usually copper), added to give it sufficient hardness to stand use.

The origin of the word *sterling* is interpreted by W. W. Skeat, the famous English etymologist, as follows:

In the twelfth century during the reign of King John of England, a group of people called "Easterlings" were invited to England to reform and perfect the English coinage. These people were called "Easterlings" because they lived on the Northeastern coast of Europe in a series of federated commercial towns along the Baltic sea. These people were famous for the purity of their coinage.

King John's invitation was accepted by a number of these "Easterlings" and ever afterward, good English money was called Easterling" or "sterling." Good silver articles other than coins came to receive the same designation.

PAUL REVERE, THE SILVERSMITH

All of us know Paul Revere because of his daring midnight ride, which is described in all of the history books. Whether this remarkable man was a jockey by trade, or how he made his living before and after his horseback stunt, is not told in the average book of American history. If one looks up the biography of Revere, however, he will find that his regular occupation was quite different from the affair that made him famous. "Gold- and silver-smith, brass founder, and copper-plate engraver" is the designation given him in the encyclopedias.

Paul Revere was born in Boston of Huguenot descent. His father and grandfather before him had been famous for their work in metals, particularly gold and silver. An article on "Old Silver" in *The Mentor* describes and portrays more of the old silver pieces of this man than of any other early American silversmith, for he was indeed in the front ranks in this field. Many of his pieces may be seen in the various museums of New England.

THE NOBLEST OF THE NOBLE METALS

Platinum is indeed the noblest of the well-known noble metals. Because of its extreme chemical aloofness, it is an

extremely desirable material for making crucibles and other fine pieces of equipment for exact chemical work. Platinum is useful in electrical devices wherever hardness and excellent conductivity are needed, particularly at a point where great heat is developed.

In the archives of France there is a carefully guarded platinum-iridium bar one meter long. This meter stick is the standard of the world. Platinum was chosen for making it because it would never corrode or tarnish or change in length a single fraction of a per cent.

Because platinum is rather scarce, it is high in price. Because it is high in price, it is much sought after as a jewelry material. This was the motive for the platinum-jewelry craze, according to Dr. Charles L. Parsons, secretary of the American Chemical Society, in a speech in 1926 before the Institute of Politics. Another chemist appearing on this same program said that if the author of the lines which refer to heaven as having streets "paved with gold" were living to-day, he would have referred to streets of platinum, instead, since platinum is a more costly metal. Dr. J. E. Teeple added that platinum would be a more suitable material than gold for paving-bricks.

Be that as it may, platinum has some very remarkable properties which will cause it ever to be sought, even if platinum jewelry should go out of style. During the War, the government appealed to both makers and wearers of jewelry not to divert any more platinum into the jewelry field for a while, because this valuable metal was so much needed to make more useful articles.

Besides resisting the chemical action of almost every other substance, platinum molecules have an almost unbelievable tendency to stick together. This is shown by its malleability and ductility. It has been estimated that one cubic inch of platinum can be drawn into a wire so fine that it would extend twice around the world.

EARLY HISTORY OF PLATINUM

From the beginning of history, gold has been more sought after than any other commodity. Platinum is worth more than

SORTING METAL BY HAND

The part which was thought to be devoid of valuable contents was rejected. The illustration shows a lack of agreement among the workers. Many of the elements were lost sight of for centuries because of these crude methods. (Woodcut from Agricola, *De Re Metallica.*)

five times its weight in gold, but Crœsus, Solomon, Pizarro, the forty-niners, and the Klondike rushers knew it not. Indeed no one knew this metal until chemists, about the latter part of

the sixteenth century, demonstrated its usefulness in the arts. The great World War showed platinum to be indispensable in the manufacture of munitions, and fashion set its stamp of approval on it as a setting for precious stones.

The textbooks say that platinum was discovered in the sixteenth century. No one person is mentioned as the discoverer of this metal because the contributions of many minds were required to recognize it as an individual element.

PLATINUM SPANGLES OF ANOTHER DAY

Two thousand or more years ago the aboriginal Indians of South America made platinum ornaments for themselves. Perforated spangles, nose rings, and other ornaments made of this metal have been unearthed in the prehistoric graves of Ecuador and other South American countries. Platinum and gold ornaments, made by hammering the two metals together, have also been found. The American Museum of Natural History in New York City has some interesting examples of early ornaments of gold and platinum from Ecuador, dating from at least two thousand years ago.

More than seventeen hundred years after the date of these prehistoric relics, Spanish miners noticed the metal and named it *platina* because of its resemblance to silver, the Spanish name for which is *plata*. Because the small grains in which the metal occurs did not appear to have any commercial value, these miners threw them back whenever they found them associated with gold or silver ores.

When, during the early part of the eighteenth century, platinum was first introduced into Europe, it was not recognized as having any value. The Spanish government, fearing that it might be used to debase coinage, ordered it buried whenever it was extracted from ore, and not shipped to Spain at all.

Meanwhile, in 1741, an Englishman named Wood brought some platina to Europe and expressed the opinion that it might

have some value. Watson, another Englishman, announced in 1750 that it contained a metal hitherto unknown. Sheffer, the director of the Stockholm mint, proved conclusively in 1752 that a new metal existed in these gray, uninteresting-looking grains.

CHABANEAU

To Pierre-François Chabaneau, a French scientist, belongs the credit for being the first person to work out a means of transforming the spongy grains of platinum into metallic ingots. Chabaneau's problem was a serious one, because platinum had been shown to be infusible even in the hottest known furnace.

Chabaneau was born April 21, 1754, and was educated for the priesthood by an uncle, who was a monk of the order of St. Anthony. He was expelled from school because he was refractory about studying the orthodox theological subjects. At the age of seventeen he found himself alone in Paris with very little money.

After serving as a teacher of mathematics in a Jesuit college at Passy, he was persuaded by a young nobleman whom he had instructed to go to Spain as a professor in a college at Bergara. While at the college at Passy he had found it necessary to study mathematics at night, inasmuch as he had had no previous training in that subject. When the position was offered to him, he was in such desperate circumstances that he kept his ignorance of the subject concealed. Not only did he master his mathematical subjects, but he also studied physics and chemistry, and became well versed in those two subjects. At this time Lavoisier was doing his most active experimental work. It attracted Chabaneau's attention and gave him much inspiration in this work.

No sooner had Chabaneau removed to the college at Bergara, Spain, than King Charles III heard of his reputation as a scientist. He thereupon created for him a public chair of Mineralogy, Physics, and Chemistry, moved him to Madrid,

gave him lodging in one of the palaces, and assigned him a salary of 2,200 piasters (about $2,400) a year. In addition, Chabaneau was provided with a magnificent library and laboratory.

About this time platina was attracting especial interest in Spain, with the result that Chabaneau set himself the task of analyzing it and preparing ingots from the grains. The task was a difficult one, because he had to prepare his own reagents and make his own apparatus. The following is copied from a little-known memoir, *Notice sur Chabaneau, Chemist Perigourdin,* written in 1857 by M. Jules Delonue:

Chemistry was still an empiric science and Lavoisier had only just begun to bring an order out of chaos. Further, at this time no one could have suspected that in addition to gold, mercury, lead, copper, iron, etc., the platinum ore contained five more metals, osmium, iridium, palladium, rhodium and ruthenium, not discovered till 1803 and 1844. Chabaneau found himself contending with six metals where he supposed there was only one, platinum. Inevitable mistakes and innumerable disappointments naturally resulted. He had proved that platinum was malleable, yet occasionally he found it despairingly brittle [this was an alloy of iridium]; he knew that it was infusible, incombustible and unoxidisable, yet he was stupefied to see it at times burn and volatilize [this was the alloy with osmium].

The Marquess of Aranda, appreciating the great interest attaching to the industrial use of a metal of which Spain possessed all the mines, came often to Chabaneau's laboratory, and often found him discouraged and busying himself on other investigations. At such times Aranda, a most congenial and lovable character, would console him, encourage him, and in the end bring him back to that which Aranda considered his great task, the investigation of "white gold," as it was then called. Chabaneau would take up with new zeal his tantalizing work, and so passed days and nights, months and years. At last, he succeeded in surmounting all difficulties, his wearisome task was rewarded by the discovery of a process by which the metal could be purified. The effectiveness of the method was verified by several repetitions. The enchanted Marquess had him carry it out on a large scale and came to the laboratory each day with increasing interest. Judge of his astonishment and horror

when one day he found Chabaneau in a frenzy engaged in throwing out the doors and windows his dishes, flasks, ores, as well as all the solutions of platinum which he had prepared with so much trouble and difficulty.

The Castilian imperturbability of the Marquess only redoubled the French fury of the young chemist. "Away with it all. I'll

ASSAYING WITH A SMALL FURNACE

"The method of assaying," says Agricola, "differs from smelting only in the amount of material used. By smelting a small quantity, they learn whether the smelting of a large quantity will compensate them for their expenditure." (Woodcut from Agricola, *De Re Metallica.*)

smash the whole business," he cried in a mixture of French and the patois of Perigord. "You shall never again get me to touch the damned metal." And in fact he broke up all the apparatus of the laboratory.

Really this infantile fury was to some extent justifiable. No one knew then, and indeed few know now, that lime does not precipitate platinum in artificial light, but that in daylight the metal is completely precipitated by this reagent. Chabaneau, working with lime at night, had been enabled to precipitate all the other metals which were present in his solution, while his platinum was left unprecipitated and purified. Repeating the operation by day, platinum and all were thrown down, and he was completely at sea, without being able to suspect the reason.

Three months later, at the home of the Marquess of Aranda there appeared upon a table an ingot some ten centimeters cube, with a beautiful metallic luster; it was malleable platinum. The enthusiastic Marquess started to pick it up but failed to move it. "You are joking," said he to Chabaneau, "you have fastened it down." "No, indeed," said the professor and he raised the little ingot easily, though it weighed some twenty-three kilograms. The Marquess had not thought that the light platinum sponge would thus appear as the heaviest of all (then known) metals.

Chabaneau's discovery consisted in compressing the platinum sponge while hot at the moment of its formation, and then hammering it several times while at a white heat. Since platinum is infusible at the highest temperature of a furnace, it is easily recognized how difficult it had been to convert the pulverulent metal into an ingot. This infusibility is, however, only relative, since Deville has since succeeded in fusing the metal with the oxygen-hydrogen blowpipe; but this property, added to a resistance to the action of acids equal to that of gold, evidently entitles platinum to rank with the precious (noble) metals.

The king, who spent some of his leisure moments dabbling in science, often came to Chabaneau's laboratory and assisted in his experiments. He was very proud to have such a discovery made in his capital, and caused a commemorative medal to be struck in platinum. He also gave Chabaneau a life pension of 3,800 piasters [$3,000], in addition to his annual stipend of 12,000 livres, but the pension was granted only on the express condition of residence in Spain, and was to be forfeited should Chabaneau leave the kingdom. The letters-patent bear the date of 1783, and thus establish the priority of Chabaneau's discovery officially and in an incontestible manner.

Chabaneau was for some time engaged in preparing large quantities of malleable platinum. Then his patron, Marquess d'Aranda, having been appointed ambassador to France (1787), he was prevailed on to accompany him to Paris, in order to convert under his auspices some of the new metal into ornaments for the crown.

PANNING A TOWN

After the real value of platinum was discovered, the inhabitants of Quibdo, the Spanish-American town from the region of which most of the platinum that was shipped to Spain had

come, remembered that miners for many centuries had been throwing away platinum waste separated from gold in the refining process. This waste had been discarded in the streets, in the cracks of buildings, or any place to get it out of the way. One man is said to have torn down a comparatively new house in order to mine beneath it. He later rebuilt the house at a profit of $4,000.

Even to-day people are recovering platinum from the sands of the Atrato, the Colombian and the Peruvian rivers, which gold-crazed Spaniards, Portuguese, English, and Hollanders threw away as worthless shortly after the discovery of America.

In the latter part of the eighteenth century, certain Spaniards made a counterfeit doubloon, a gold coin worth about $8.24 at the time. These coins were struck from platinum and gilded. They were difficult to detect because the specific gravity of gold is almost the same as that of platinum. The platinum in the counterfeit coins would now be worth about $40.

RUSSIAN PLATINUM

Although platinum was first found in South America, Russia has since come to rank first in platinum production. The metal was first found in Russia in 1822 in the Ural Mountains. Mines were opened in large numbers. At the time of the Russian revolution, the vaults of the state banks were found to yield $200,000,000 worth of gold bars, and over $2,600,000 worth of 96 per cent pure platinum.

Although platinum usually occurs in grains, a few nuggets of some size have been found. The largest platinum nugget that has yet been discovered was somewhat over twenty-five pounds in weight, measuring 7 by 4 by 3 inches in size. This was found in Russia and was called the great Demidov nugget, because it came from the mines by that name.

After the discovery of platinum in Russia, the Russian

government issued a platinum coinage, reckoned at approximately one-third that of gold. The Russian platinum coinage, begun in 1828 in the reign of Nicholas I, consisted of three-ruble, six-ruble, and twelve-ruble pieces, worth at par $2.40, $4.80, and $9.60, according to the value of the ruble at that time; the coins contained about 2 per cent of iridium. The nominal worth of these coins was about $3,000,000, but the metal in them now would bring nearly $50,000,000.

SOUTH AMERICAN PLATINUM

Colombia, in South America, has been known for a long time to possess platinum ores, but it has only been since the War that its platinum resources have been worked extensively. A vast region, consisting of over five thousand square miles, lying west of the central ridge of the Colombian Andes in the drainage basin of the Atrato and San Juan rivers, and extending south of the latter to the Mira River, began to be worked extensively only a few years ago. In 1910 Colombia exported $31,383 worth of platinum to the United States. In 1913 this amount had increased to $2,241,744. The amount has been increasing steadily ever since.

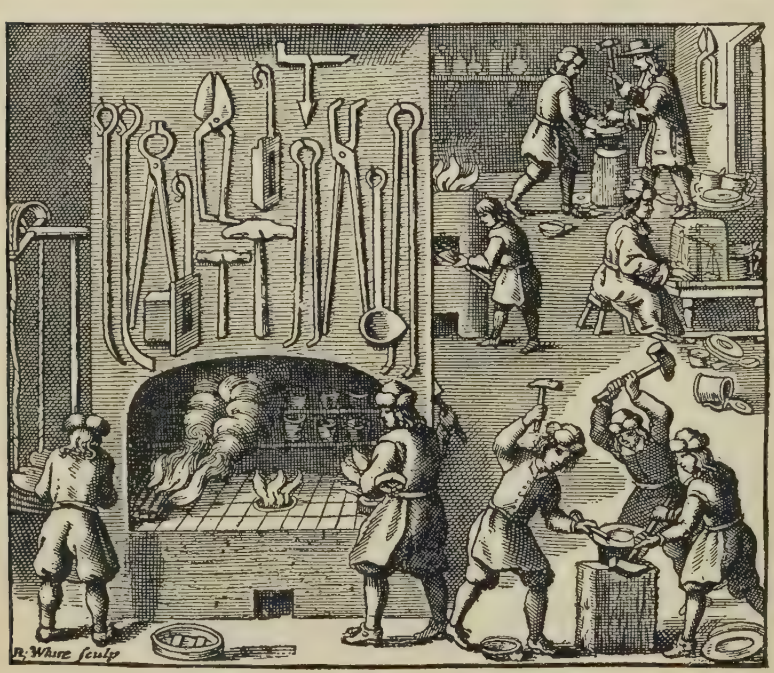
No doubt platinum is very widely distributed geographically. Perhaps its price will come down materially, since new fields have been opened in Spain, in the Ronda Mountains near the coast. Alaska likewise has been found to contain some platinum.

NEW PLATINUM DISCOVERIES

The world's production of platinum in 1912 was 279,036 ounces, of which 250,000 ounces came from the Ural mines of Russia. The recent war interfered with the Russian production of the metal, so that in 1924 there were but 104,527 ounces produced in the world, despite the fact that Colombia had meanwhile increased its production markedly. As a result,

prices rose from about $40 an ounce in 1912 to an average of $112 an ounce in 1924.

Discoveries of platinum in Africa in 1923 would seem likely to bring down the high price of platinum which still prevails.



THE SHOP OF A MEDIEVAL SILVERSMITH

Note the emblems of the silversmiths' craft on the wall. (From the Bagford Collection, British Museum.)

A. W. Marberry, writing in the *Engineering and Mining Journal-Press,* states that the Transvaal is capable of supplying as much platinum as the world can consume. He predicts a 50 per cent decline in the price of platinum in the next half-dozen years.

PLATINUM PIRATES

Two men were arrested in April, 1920, when they tried to dispose of 280 troy ounces of platinum sponge. They had

tried to sell small lots of the porous platinum to two different firms who had circulars concerning various platinum thefts. After the arrest of the men, some of the remainder of the sponge was found in a rubber hot water bottle which they carried in a satchel.

Immediately after the arrest of the men, the platinum was analyzed in order to determine its origin. All platinum owned by the government or used in different industries is carefully catalogued, and its exact composition known—that is, the exact percentage of iridium, palladium, etc., present in it has been determined.

Since the Bureau of Standards, the Roessler and Hasslacher Company, of Perth Amboy, and the Universities of Missouri and of Louisiana had reported losses of spongy platinum, it was thought that the stolen metal could be traced to one of these sources. The grand total of that lost, however, was less than what was recovered from the arrested men. Chemical analysis, moreover, indicated that the material had not come from any of those places, but apparently had been taken from the stock at a government military plant at Jacksonville, Tennessee. At least it corresponded with the analysis of the 13,800 ounces which had been stored there.

Investigation showed that in eighty-six cans of what was supposed to be platinum sponge stored in a safe in the Jacksonville plant, a mixture of mercury and dirt had been substituted. One of the men arrested had previously worked as a salvage foreman at the Jacksonville plant. He is still serving a long term in prison, but he has never to this day revealed the hiding place of the remainder of the platinum that he or some one else took. When his term is over, what then?

PLATINUM AND THE WAR

The need of platinum during the War was acute. The supply of this metal from other countries was virtually shut off, and

more than 50 per cent of that in this country was in use for jewelry. The Women's National League for the Conservation of Platinum was formed, and every effort was made to discourage the use of this metal for ornamentation. Writing about the shortage of platinum in this country in 1918, Dr. Parsons, of the American Chemical Society, made the following statement, as reported in the *Literary Digest:*

It is perhaps not realized by the public that platinum is necessary in the production of nitric and sulphuric acids, essential in all explosives.

It is absolutely essential in the manufacture of special pyrometers, and no gun can be made without the use of a pyrometer.

Some necessary signal instruments are dumb without platinum.

Platinum is essential in the composition of certain delicate gun-mechanisms.

The rapidly growing chemical industries, engaged in war work, need platinum in their laboratories.

Platinum is required in the new plants the government is erecting with such feverish haste for the manufacture of nitrates from the air, these nitrates being needed for fertilizers and munitions.

Without platinum all experiments in gases would be greatly handicapped.

The so-called platinum used in electrical work is, like the jewelers' platinum, an alloy of platinum and iridium, but with this difference, that the proportion of iridium is ordinarily greater in electrical platinum than in jeweler's platinum, and for some work may be as high as 50 per cent. Unless one is informed he does not realize that each telephone and telegraph instrument has platinum contacts, that every high-grade magneto for aeroplane, automobile, motor-boat, or gas engine has from two to six contacts of platinum, and that the multitude of contacts on the telephone switchboard, on the relay instruments of both the telephone and telegraph lines, are of platinum.

There are a large number of different kinds of electrical-control systems in which platinum is used, one of the most important of which consists of the thermo-couples for the electrical control of heat in furnaces and ovens for a variety of purposes. While the quantity of platinum in any single piece of electrical equipment is very small and its value almost negligible in comparison to the value of the whole instrument, yet the great number of these instru-

ments, which have been and are being made for the government work, calls for an unbelievably large quantity of platinum and iridium.

PLATINUM USED IN SURGERY AND DENTISTRY

The "nobility" of platinum makes this metal of value to surgeons and dentists. Surgeons use platinum to replace sections of bone and to brace shattered joints. It is useful for such purposes because it will not act chemically under these circumstances.

The dental profession uses about 30,000 ounces of platinum a year. One of the chief dental uses for the metal is for making pins for artificial teeth.

TIPS OF PEN POINTS

Two of platinum's close relatives, osmium and iridium, both quite as noble in nature as platinum itself, are used to a considerable extent in tipping fountain pens.

Gold was first used in the making of pen points in the United States in 1835. Soon it was found necessary to harden the points of pens, and this was done by protecting them with diamonds or rubies, which made the pens very costly and consequently very rare.

The discovery was later made that an alloy of iridium and osmium soldered to the gold would serve the purpose just as well as the gem stones and at much less cost. An alloy of platinum with 10 to 20 per cent iridium is the hardest metal known, but is much too expensive for ordinary use.

PLATINUM HAS A RIVAL

A recent article in the *Engineering and Mining Journal* of New York described tantalum, a noble metal which is not very well known, as a serious rival of platinum. This metal is

Photograph by Ewing Galloway

A GOLD AND SILVER MINE AT SILVERTON, COLORADO

white in color, though not so bright as platinum; but it can be worked cold, drawn, hammered, machined, polished, hardened, rolled, drawn into wires, and punched.

The most remarkable property of tantalum is its unusual

resistance to chemical corrosion and to the action of acids. Because of its extraordinary resistance to reagents, its discoverer, Ekeburg, a Swedish chemist, gave it its name. It was discovered in 1802.

Tantalum was the first metal to be used in commercial quantities for the manufacture of electric light filaments. In 1910, five million feet of tantalum wire were used in the United States for making incandescent lamp filaments. Since the discovery of a method for drawing tungsten into filaments, the amount of tantalum used for this purpose has declined, because tungsten gives a brighter light with less current.

Even with this decline in one of its uses, tantalum bids fair to find other important applications. It is not expensive, it can be given a wonderful polish, and even a wonderfully iridescent sheen. A number of people are experimenting with it as a substitute for platinum and silver in surgery and dentistry, and as a semi-precious art metal.

PLATINUM'S ASSOCIATES

When platinum is found in nature, a number of metals are usually found closely associated with it. These are iridium, osmium, ruthenium, rhodium, and palladium.

Alloys of iridium and osmium, and of iridium and platinum, have many useful applications. Ruthenium is little used, although rhodium serves about as well as platinum for making crucibles and electrical equipment, and as a catalyst. It seems that the quantities of rhodium used for such purposes are likely to increase.

WHITE GOLD

Palladium, a noble metal which many people wear without being acquainted with it, occurs in "white gold." White gold consists of 18 parts of gold to 6 parts of palladium.

Palladium is likewise important as a constituent of dental alloys and in the making of some scientific instruments. It may some day outrank platinum in the quantity used. For the matter of that, some of the noble metals which are not used now at all may come suddenly to the front.

People are willing nowadays to try new types of stuff for new purposes, even without a precedent to buoy up their hopes. And so, in the future, we may have tantalum, or rhodium, or ruthenium mountings for engagement rings. And the girl receiving such a ring will brag about it to her best friend.

Photograph by Ewing Galloway

SALT—ONE OF MAN'S MOST PLENTIFUL AND IMPORTANT KINDS OF STUFF

Partial view of the fields of the Inland Crystal Salt Company, Utah, with the refinery in the distance.

CHAPTER XVII

SOCIABLE STUFF

Potassium and Sodium are the names by which I have ventured to call the new substances.

—Sir Humphry Davy

SOME metals do not act in the aloof manner characteristic of the so-called noble metals, but they strike up partnerships with everything with which they come in contact. These exceptionally sociable metals therefore are found in nature only in chemical combination with other elements. This is the reason why they have been isolated only in comparatively recent times, while gold, silver, and others of the inactive metals were known for thousands of years.

The sociable metals, placed in the order of their friendliness toward other elements, are cæsium, rubidium, potassium, sodium, lithium, barium, strontium, and calcium. All of these

will combine with cold water and with air to form their hydroxides and oxides respectively. Small chance they would have, therefore, of ever being found in the free state in nature.

Compounds of some of the very active metals have been known since the earliest times. Soda, salt, potash, saltpeter, and lime were among the earliest kinds of stuff used by man. Soda—formed by burning wood—has been found to be a carbonate of sodium; salt is sodium chloride; potash is potassium carbonate; saltpeter is potassium nitrate; and lime is calcium oxide. Because these compounds successfully resisted decomposition for centuries, they were looked upon as elements. It was not until the discovery of the voltaic cell that the extremely active metals were separated from their compounds.

ISOLATION OF SOME ACTIVE METALS

Sir Humphry Davy was the first scientist to isolate sodium, potassium, and some of the other active metals. Potassium was the first of these metals to be separated from its compounds by the process of electrolysis. This great achievement was accomplished in 1807.

One hundred years after Davy's isolation of potassium, a celebration was held at the Royal Institution of Great Britain to commemorate the event. On this occasion, Professor I. E. Thorpe, the well-known English scientific historian, was the chief speaker. The following is taken from his remarks:

> So far as can be ascertained, it was on October 19, 1807, that he [Davy] obtained his first decisive result. This is thus described in Davy's own handwriting in the *Laboratory Journal,* which has been preserved for us by the pious care of Faraday, and which is one of the most precious of the historical possessions of the Royal Institution. When potash was introduced into a tube having a platina wire attached to it, so, and fused into the tube so as to be a conductor—i.e., so as to contain just water enough, though solid—and inserted over mercury, when the platina was made nega-

tive, no gas was formed and the mercury became oxydated, and a small quantity of the alkaligen was produced round the platina wire, as was evident from its quick inflammation by the action of water.

When the mercury was made negative, gas was developed in great quantities from the positive wire, and none from the negative mercury, and this gas proved to be pure oxygen—a capital experiment, proving the decomposition of potash.

Few discoveries of like magnitude have been made and perfected in so short a time, and few memoirs have been more momentous in result than that which, put together in a few hours, gave the results of that discovery to the world.

The whole work was done under conditions of great mental excitement. His cousin, Edmund Davy, who at the time acted as his assistant, relates that when he saw the minute globules of the quicksilver-like metal burst through the crust of potash and take fire, his joy knew no bounds; he actually danced about the room in ecstasy, and it was some time before he was sufficiently composed to continue his experiments.

The rapidity with which he accumulated results after this first feeling of delirious delight had passed was extraordinary, and he had obtained most of the leading facts concerning the physics and chemistry of the new substances before the middle of November. . . .

Soda, when acted upon in the same manner as potash, exhibited an analogous result; but the decomposition demanded greater intensity of action in the batteries, or the alkali was required to be in much thinner and smaller pieces.

The substance produced from potash remained fluid at the temperature of the atmosphere at the time of its production; that from soda, which was fluid in the degree of heat of the alkali during its formation, became solid and cooling, and appeared having the lustre of silver.

The discovery of sodium and potassium by the use of the voltaic cell led Davy to investigate other substances which he believed to be undecomposed compounds. In 1808 he succeeded in isolating barium, calcium, and strontium in the same way.

The compounds of cæsium, rubidium, and lithium (closely

related metals) are so scarce that their existence was not even known by Sir Humphry Davy. One by one they were detected later by means of the spectroscope as impurities in other compounds, and they were later isolated electrolytically.

The chief and almost the only practical use which the exceedingly sociable metals have found for themselves is in television. Sodium and potassium are the two chief metals used for this purpose, although cæsium and rubidium have been found to be excellent. Barium may also be used. The secret of television is the fact that these extremely active metals are sensitive to light to the extent that an electric current is set up when light shines on an evacuated tube, the inside walls of which are lined with one of these metals.

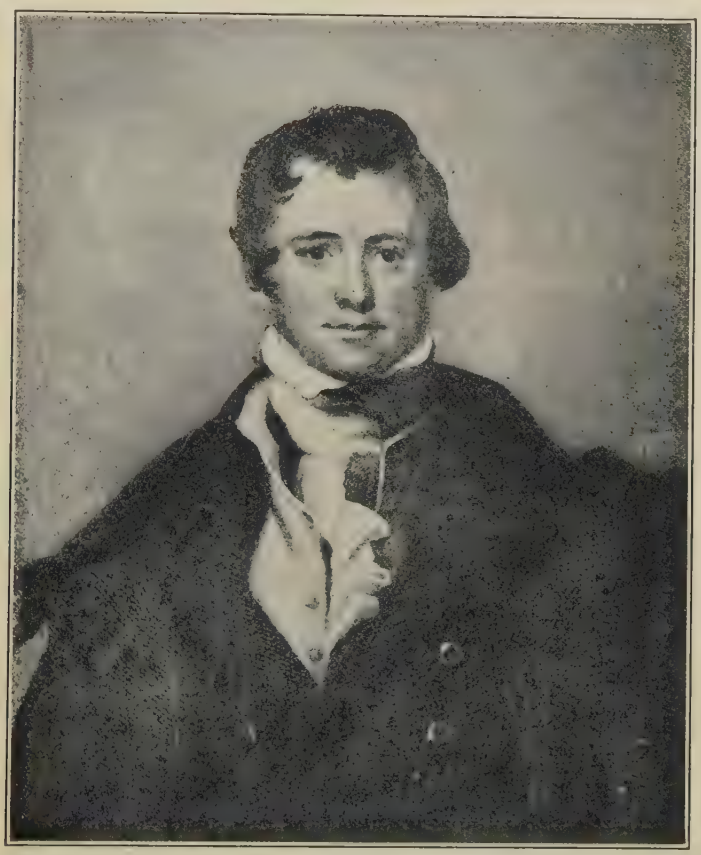
SIR HUMPHRY DAVY

The discovery of a means of breaking up century-old partnerships of the sociable metals is not the only noteworthy achievement of Humphry Davy, the great English scientist.

Davy's career was an interesting one. He was the eldest son of Robert Davy, a wood carver, and his wife Grace Millett. Davy was born in 1778, and his father died when he was sixteen years old. Although his father had been an excellent carver, he was a poor business man; and he left his widow with no means except a home. She placed a mortgage on the house, but it was necessary for Humphry to leave school in order to help support the four younger children. He became apprenticed thereupon to Dr. Bingham Borlase, an apothecary living in Penzance, his home town. He at once began to study natural philosophy privately. One of the first books he read was an English translation of Lavoisier's *Elements*.

From reading and speculation Davy soon passed to experiment. At this time he had never seen a chemical operation performed. He collected what paraphernalia he could command. The common mineral acids, the alkalies, and a few

drugs were his chemicals. Phials, wineglasses, teacups, and tobacco pipes, with an occasional earthenware crucible, were his pieces of apparatus. It was while he was preparing to launch on his scientific experiments that he wrote the following



SIR HUMPHRY DAVY

This portrait, painted by Sir Thomas Lawrence, hangs in Burlington House, Piccadilly, of the Royal Society of London.

memorable passage in his diary: "I have neither riches nor birth to recommend me; yet if I live, I trust I shall not be of less service to mankind than if I had both of these advantages."

Davy had scarcely begun his nightly laboratory work when

an incident occurred which led to his invention of the safety lamp that bears his name. Dr. Borlase, for whom he worked, had just returned from his day's rounds when he told his family (young Davy being present) about a fearful explosion in one of the Welsh coal mines. The graphic description of the fate of the eighty-nine men who were entombed in the mine by the explosion deeply stirred the lad. Other similar tragedies, recurring with a frequency that was startling, kept him at his labors constantly.

The first safety lamp which he devised he showed to Mr. Tonkin, a man who acted as his benefactor after the death of his father. In his lamp the flame burned quietly inside the chimney, but would not go out through the concentric tubes at the top of the chimney, even though there was an explosive mixture of gases surrounding it. Tonkin found, however, that the one difficulty with the lamp was that when fire damp (methane) surrounded the lamp, the light was quickly extinguished. At the very time when the miners needed light, therefore, the light was gone. Not until Davy was thirty-eight years of age was he able to correct this vital defect in his extraordinary device. The final lamp which Davy perfected had a fine-mesh metallic webbing replacing the glass chimney of his original device. If the air surrounding this lamp be charged with an explosive gas, it would enter through the meshes of the web and burn inside the cage, while that without would remain unkindled. The peculiar appearance of the flame would serve as a warning of danger to the miners and cause them to evacuate the mine.

During Davy's nineteenth year he made some interesting studies other than those relating to his work with the safety lamp. He became acquainted with a boy near his own age, Gregory Watt, son of the engineer, James Watt, who had invented the steam engine. This acquaintance stimulated him to go further into the study of the theories of combustion than he had previously done, and to lay the foundation of later

important work on chemical theory. He also met another prominent man of the time—Josiah Wedgwood, the eminent potter of Staffordshire. The potter called upon Davy to discuss with him the different types of clay in the neighborhood of Penzance, he having learned that the lad had made a study of the geology of the region. Davy told him that he had observed that certain very fine clay deposits were undoubtedly formed by the weathering of certain kinds of rock, and he was able to point out some deposits which he had found.

Through Josiah Wedgwood, Davy was introduced to Wedgwood's brother Thomas, a chemist. Thomas Wedgwood told Davy that he had discovered means of copying pictures upon glass by the action of light. He explained that he used a solution of lunar caustic, or silver nitrate, as the agent sensitive to light. As a result of learning about Thomas Wedgwood's work, Davy made some interesting investigations on the refraction of light.

When Davy was twenty years old, he left his native town for the first time. During the process of some experiments with light refraction and photography, he had made the acquaintance of Davies Gilbert, a scientist who later became president of the Royal Society. It was through this man's influence that Davy was offered a position in a so-called pneumatic institution at Bristol for the cure of diseases by the inhalation of gases. In this institution, he acted as assistant to a Dr. Beddoes, the chief scientist on the staff. While employed there he discovered the anæsthetic properties of nitrous oxide, or laughing gas. This discovery brought him into prominence and led later to his engagement as lecturer at the Royal Institution of London.

In 1820 Davy became president of the Royal Society, the greatest scientific honor that can come to a person in England. He was quite proud of his honor, particularly since his mother, for whom he had always had the greatest devotion, was still alive to share his joy with him. Tonkin, who had been

opposed to his leaving Penzance, had unfortunately died before his protégé came to distinction.

While carrying on his experimental work at the Royal Institution, Michael Faraday came to work as Davy's assistant. It was through Davy that Faraday became interested in electricity, and it was under Davy's tutelage that he began the work which eventually led to such remarkable discoveries in this field.

Davy was knighted for his scientific discoveries, and was paid a sufficient sum to enable him to travel and meet the other great scientists of his time. He unfortunately died when he was but fifty-one years old.

SODA ASH

Even after Davy's isolation of some of the extremely active metals, these metals never came into commercial importance. Although the metals themselves cannot be seen except in museums and chemical laboratories, we use their compounds every minute of the day. Soda ash, or sodium carbonate, was the first sodium compound to achieve industrial importance. It was employed long before the days of King Snefru as a detergent in laundering. The ancients also used it in glass-making and in operations calling for an alkali. It was originally obtained solely from wood ashes, but it now can be made very cheaply from common salt by at least two methods.

To-day we use soda ash as a source of caustic soda, or sodium hydroxide, which in turn is used with fats to produce soap. Soda ash is also used with sand, lime, and other ingredients to form ordinary glass. It features conspicuously in the manufacture of many drugs, chemicals, and scouring compounds, as well as in dyeing and leather-tanning. Soda ash holds about the same place among the alkalies as sulphuric acid does among the acids. There is scarcely an industry that does not use large quantities of it.

SALT

Salt is the commonest of the compounds of sodium. It is a substance which consists of the elements sodium and chlorine.

SACRED SALT

Salt has, from ancient times, played a prominent part in many superstitions and religious rites. Many early sacrifices to gods and idols had salt sprinkled on them as an additional offering to the gods.

The ancient Chinese people worshiped a salt deity which they called "Phels." Many ancient peoples living inland considered the bank of a salty stream to be an ideal place to pray. Among a considerable number of ancient peoples, the eating of salt together was a ceremonial mark of lasting friendship. The scattering of a few grains of salt was also considered a symbol of sealing a contract.

The ancient Romans regarded salt as the staff of life, and they used it in many of their sacred rites.

Horace, in one of his odes, says that the man who enjoys life is one whose father's saltcellar gleams on the table. This refers to the ancient Roman custom of handing down the saltcellar from one generation to another because of its quasi-sacred nature. Horace writes a satire in which he says that bread with salt is much better for the growling stomach than dainty viands.

"ABOVE THE SALT"

In medieval times the saltcellar on the table was the dividing line of social standing. The gentry sat above the saltcellar, while those of less aristocratic birth sat below it. This caused much attention to be paid to the design and workmanship of the salt container.

IMPORTANCE OF SALT

Professor Charles W. Super, writing for *Popular Science Monthly,* points out that there are a number of references in ancient literature to peoples who are said to have lived without salt. For example, Sallust, in his *History of the Jugurthine War,* says that the Numidians lived chiefly on milk and the flesh of wild animals, and that they used no salt or other relishes.

In the *Odyssey,* Teiresias the seer directed Ulysses to travel until he came to "men who know not the sea, neither eat meat flavored with salt." Other similar references could be cited. The point that is not clear, however, even though certain peoples were supposed to have lived without salt as such, is this: might not these "saltless" persons have obtained this substance in some other foods which they ate? Our physiological chemistries of to-day give us many notes on the importance of salt in the body, and it is difficult to believe, in view of facts which are now pretty well established, that the human body could survive without small amounts of this compound.

Professor Super gives the following references to the importance of salt to living organisms. Salt is sought for and eaten by animals. Some birds are said not to be able to eat quantities of salt without fatal consequences, but the same is not true of other animals. It seems to have no ill effect on barnyard fowls. Cattle eat salt and seem to relish it.

A famous salt spring or "lick," found in Boone County, Kentucky, is mentioned in a *History of Kentucky* by Shaler. This spring is called Big Bone Lick. Shaler writes as follows:

> Not only do we find the bones of animals which occupied the country when the whites first came to it—the buffalo, the elk, the deer, etc.—but also deeper in the mire, or in portions that indicate a greater antiquity, great quantities of the bones of the fossil elephant, his lesser kinsman, the mastodon, the musk-ox, an extinct

long-legged buffalo, the caribou or American reindeer, and various other creatures which dwelt here in the time when the last glacial period covered the more northern regions with a mantle of ice.

The reason for the enormous number of skeletons found buried near the Big Bone Lick is thought to be the craving for salt by these animals. The spring is surrounded by a swampy region. In their eagerness to get at the brine, many animals rushed in beyond their depth. Some of them may even have been tramped under foot when large herds stampeded to get to the salty water. Small animals as well as large ones were found to have perished near the "lick."

THE MEANING OF SALARY

The word *salary* very curiously is derived from the word *salt*. The Romans considered salt as a necessity to their soldiers. Consequently, each soldier was provided with a special ration of it, called *salarium argentum,* or "the salt stipend." Civil officers were also given this ration of salt when they traveled any distance. Later, when the article could be obtained almost anywhere, a certain sum of money was given each soldier and civil officer for the purpose of purchasing his salt wherever he might be. The salt money or salary became less important as time went on, but the term gradually came to be applied to any fixed sum of money, whether or not it was given for the purpose of buying salt.

ANCIENT TRAFFIC IN SALT

As far back as historical records go, salt has played an important part in human affairs. Many of the caravan routes of to-day had their origin as roads over which camels freighted the salt of Indian mines to the Mediterranean markets. Some of these early Hindu mines are still in operation.

Certain regions of northern Africa, too, have served as store-

houses for salt since time immemorial. Some portions of the Sahara are covered with a crust of salt so thick that it looks like snow. In some of these regions, houses are said to be built of rock salt blocks cemented together with mud and roofed with camel skins. There is no danger that they will dissolve, as there is no rainfall in the region.

Some of the earliest improved roads were established to accommodate the traffic in salt. The *Via Salaria* in Italy served two thousand years ago to allow ox-drawn carts to transport salt from the salt pans of Asia to the Roman Empire.

SOURCE OF SALT

Where does salt come from? Why are certain regions of the globe blessed with large quantities of it? It occurs in great veins or layers of almost pure mineral, generally found under thousands of feet of earth, clay, or rock, and it is obtained from the water of salt springs, salt lakes, or the sea.

In ancient times the sea supplied practically all of the salt used, and in some countries it does to this day. These are the countries with large seacoasts and long, hot summers. The sea water is run into large, shallow ponds where the water evaporates, leaving the salt to be gathered.

The sea is constantly becoming saltier. Countless streams and rivers wash more salt into it. The sun evaporates the water, leaving the salt behind. And then the water which has evaporated comes down over the land in the form of rain and washes more salt into the streams and rivers, and then into the seas. So the process keeps up forever.

The source of salt, as commercially produced in this country, is the great salt deposits. These are the beds of prehistoric salt lakes or seas which have long since dried up.

The largest salt mine in this country is located at Retsof, New York, in Livingston County, about 31 miles south of Rochester. This mine has been in existence since 1886, and

the underground excavations now consist of approximately 90 miles of tunnels, 30 to 50 feet in width.

SALT MINING

The method of mining salt is similar to that of mining coal. All machinery used is driven by electric power. The operation

Photograph by Ewing Galloway

INTERIOR OF A SALT MINE

The huge pillars of solid rock salt are left to support the roof.

consists of undercutting the salt and then removing it from the vein by blasting. Refined salt is mined by putting down a pipe and pumping down water to dissolve it.

TAX ON SALT

Dr. Geoffrey Martin, in his *Modern Chemistry and Its Wonders,* says that "since time immemorial, when nations have needed to raise the largest possible revenues, the heaviest burdens have fallen on the necessities of life, and almost from the earliest of times, salt has had to carry a heavy portion of the load. In Italy and Spain and in other countries where the

salt tax has been enforced, this led to extensive smuggling and bloody affrays between custom house officials and salt runners."

The income of the salt tax in Germany in 1913 was 64,000,000 marks, but it dropped to 7,000,000 marks in 1925, because the government allowed the salt to be denatured for industrial purposes. Just as alcohol, denatured with chemicals that make it unsafe as a beverage, is sold for industrial purposes, so salt, denatured with soda, mineral oil, or iron rust, is sold tax free in certain countries, the denaturant allowing the salt to be used in chemical industries, but not as an addition to food.

OTHER EVERYDAY SODIUM COMPOUNDS

Soda ash and table salt are the two sodium compounds used in the largest quantities, but others are also quite important.

We might not get a sufficient quantity of food, for example, if nature had not supplied us with a plentiful amount of sodium nitrate or Chili saltpeter. This compound, now either made synthetically or taken from nitrate beds, is one of the most important nitrogenous fertilizers. Sodium nitrate is not satisfactory as a constituent of gunpowder because it draws moisture when stored; but it can be changed without much trouble into potassium nitrate—the basis for most important explosives.

Then, too, we use sodium tetraborate—borax—as a water softening agent; sodium hypochlorite as a household disinfectant; sodium bicarbonate or baking soda in fire extinguishers and in baking powders; sodium hyposulphite or "hypo" as a photographic developer; and sodium silicate to preserve eggs and to hold the veneer on wooden furniture.

SILICATE OF SODA

Silicate of soda or sodium silicate is a general name given to a number of considerably different commercial products.

They are manufactured by fusing together silica (sand) and an alkaline soda salt such as soda ash to form a kind of glass. By special processes on a large scale, this glass can be made to dissolve in water; hence, one name for the silicate is *water glass*.

Sodium silicate is quite valuable as an adhesive, and is used as a cementing agent for paper, wood, glass, metal, and pottery. Likewise it may be used as a binder for various materials such as synthetic building boards, furnace linings, and patching cements. Another general class of uses is as protective or preservative coatings for wood, paper, and concrete.

POTASSIUM AND POTASH

Potassium, the metal, although it is soft and so active chemically that one usually thinks of it as being of no practical use, serves a wonderful purpose as the coating of the inside of photo-electric cells, the electric eyes of picture transmission and television. Potassium compounds also are quite as important, although they are not so plentiful as those of sodium.

Potash or potassium carbonate, originally obtained from the ashes of certain plants, was the first potassium salt known. At the present time, the amount of potash secured by this ancient method is negligible, as it now comes from deposits found in certain parts of the world, notably near Strassfurt, Germany, and in Alsace. Before the war, the German-owned deposits of potash were about the only ones worked to any extent.

It was Liebig, the great German chemist, who discovered in 1860 that potassium was an essential element for plant growth. It was because of the work of this scientist that Germany developed its potash deposits as a source of valuable fertilizer material. Incidentally, potassium salts are needed in the production of most fertilizers. Therefore Germany had a corner on the potassium market when the War broke out.

The War taught the rest of the world the importance of developing all possible potassium resources. Spain, Poland, Russia, Italy, and many other countries are working diligently in an effort to become independent as far as potassium resources are concerned. The Shepherd bill, passed in this country in 1923, authorized the appropriation of $5,000,000 for prospecting with core drills for potash in the United States. In a few years this country expects to be entirely independent with regard to potash.

THE DEAD SEA NOT DEAD

The *Encyclopedia Britannica* mentions the fact that the Dead Sea contains accumulations of potassium salts. This fact seems to have been ignored commercially, however, until quite recently. It was only a very few years ago that a company was formed to secure and market salts from this sea in an effort to give Great Britain potash independence.

The following letter, written by F. E. Hamer, editor of the *Chemical Age,* of London, appeared later in the *Industrial and Engineering Journal* in this country:

> Attention has been drawn here from time to time to the possibilities of developing, from the chemical side, the natural resources of Palestine, in particular the salt waters of the Dead Sea, which are said to represent a large content of potash, as well as smaller proportions of bromine, magnesia, caustic potash, and common salt. More than one party of chemical experts have made tours of the country, and over a year ago the Colonial Office and the government of Palestine publicly advertised for a concession of from 21 to 25 years to exploit the Dead Sea salts. There was not a large response naturally, owing to the technical and financial problems involved, the difficulties of plant, transport, and commercial organization, and the magnitude of the project which in itself excluded any but the largest firms from consideration. It is now announced, however, that certain tenders have been received and that a government concession is about to be granted.
>
> A Colonial Office committee which was appointed some time

ago to investigate the possible commercial utilization of Dead Sea brine for the manufacture of potash and other salts, reported that, from a technical standpoint, there is no insuperable difficulty in extracting 100,000 tons of potash a year from the salts of the Dead Sea. By the natural process of solar evaporation, a deposit is left which contains about 70 per cent of potash, the remainder being made up of other salts. Major Brock, in a report to the government, investigated the mineral wealth of the Dead Sea, and estimated that the deposits of potash, after concentration, amount to 2,000 million metric tons; the supplies, in fact, he regarded as practically inexhaustible.

If these estimates are approximately accurate, the scheme would supply Great Britain and the Empire with an entirely independent source of potash. There are, of course, great engineering, chemical, and other problems to be solved—such as the pumping and evaporation plants, the treatment of the recovered deposits and their preparation for commercial uses, the construction of means of transport, and the marketing of the products throughout the world.

THE ALKALINE EARTH METALS

Three of the eight most active metals, namely, barium, strontium, and calcium, have been grouped together by chemists into the so-called Alkaline Earth Family. An anonymous poet was inspired to pen the following lines about this chemical group:

> The Alkaline Earth Metals three,
> Are plenteous as plenteous can be;
> But to their compounds they stick—
> And it takes quite a trick,
> To get any one of them free.

Barium has been known for five hundred years or so in the compound barytes or heavy spar, which is the sulphate of the metal. When the free metal was isolated electrolytically by Davy in 1808, it proved to be a pale yellow metal which oxidized very quickly in air. Davy gave it the name *barium*, which he coined to mean "the metal of barytes."

Strontium had also been known since the early Middle Ages

in the mineral strontianite, so called because it was first found near Strontian, a village in Argyllshire. This compound proved to be strontium carbonate. The metal was isolated by Davy the same year as barium, and proved to be white, soft enough to be cut with a knife, and easily attacked by air or water. Calcium or the "metal of calx or chalk," so named by Davy after he succeeded in wresting it free of its compounds, was likewise found to be so active that it soon became changed to lime when exposed to air.

BARIUM AND STRONTIUM FIND USES

None of the compounds of barium or strontium were known or used by the ancients. For that matter they are used at present only to a limited extent. One of their most interesting uses is in pyrotechnics. Barium compounds color a flame green, and strontium salts gives it a bright red hue. These comparatively unimportant elements therefore make their presence felt each Fourth of July. A few other uses of these compounds are somewhat important. The synthetic blonde, for example, owes her golden tresses to barium peroxide, a compound which reacts with sulphuric acid to yield hydrogen peroxide.

In sugar-refining, either barium, strontium, or calcium compounds may be used in the desugarizing of beet molasses. As a matter of fact, the barium and strontium processes give the best results. But the calcium process is used much more extensively because of the cheapness of lime.

Metallic barium is usually thought of as a museum substance. Quite recently, however, it has found an exceedingly important everyday application. This metal is being used extensively in repeater tubes, which are used to preserve the volume and clarity of sounds in long-distance and other telephone systems. A barium-coated tube requires less than one-tenth the power consumed by a tungsten tube. This saves

$120 during the life of each tube, which is approximately 10,000 hours. So small an amount of barium is required to coat a tube that about half an ounce of the metal saves $7,000,000 for the telephone company.

Strontium, barium's nearest relative, cannot yet boast of any application while in the elementary state. Even calcium, which is much cheaper and more plentiful, can only brag about its usefulness when it is combined with other elements.

LIME

Lime or calcium oxide, the commonest compound of calcium, has been used since time immemorial. It served the ancients of six thousand years ago as a constituent of mortar and as their sole alkali. The ancients produced this substance in the same way as we do to-day—by burning limestone. Limestone consists of calcium carbonate. When heated, carbon dioxide escapes as a gas, and calcium oxide is left.

The present uses of lime can be classed broadly as agricultural, constructional, and chemical. As a constituent of fertilizers, sprays, mortar, plaster, cement, stucco, and whitewash, it is known to everybody. In the chemical industry it serves as one of the basic raw materials common to almost every industrial process.

CLEOPATRA CHALLENGES THE CHEMIST

There are many more highly refined types of calcium carbonate, all differing in the arrangement of their constituent atoms with respect to each other. Thus we have chalk for writing on blackboards, marble for ornamenting the corridors of our public buildings, and calcite, a beautifully crystalline mineral, usually transparent, often used in optical instruments; to say nothing of coral, pearls, and a whole bevy of other forms of the same compound.

It was with the most expensive form of calcium carbonate—a choice pearl worth a fortune—that Cleopatra chose to show off before Mark Antony when he was visiting her realm. It is told on good authority that this fickle queen exhibited the pearl to Antony and then tossed it into a glass of wine and drank the combination.

Chemists, attention! What compound of calcium did the foolish queen drink?

CHAPTER XVIII

GAS BAGS

What's the news of the day
Good neighbor, I pray?
They say the balloon
Has gone up to the moon.
—Old English Rhyme

WHERE is there a living person who has not at some time or other wished that he could sail through the air like a bird? The idea of flying has had a great fascination for practically everybody from ancient times down to the present. Ancient legends about gods and mortals who possessed wings have come down to us, and they are just as interesting to-day as they were thousands of years ago when they were fabricated.

The alchemists of the Middle Ages still clung to the belief of the ancients that the advantages conferred upon birds might in some way be shared by men. Although these superstitious men were not clear as to how this was to be accomplished, they wrote quite a number of fanciful works in which they pretended that flying was a certainty. As with their boasts about changing lead into gold, however, the mere statement of the thing as a fact did not make it true.

Many people of the Middle Ages, spurred on by the optimistic sayings of the alchemists, began to make attempts to fly. The first experimenters pinned their faith on wings constructed in the shape of those of birds. They reasoned that human beings should be able, by means of these contrivances, to propel themselves through the air.

THE AMBITIOUS ABBOT

One of the men whom history records as attempting to fly with a pair of wings was an Italian priest and alchemist who, during the early part of the sixteenth century, was made Abbot of Tungland in Galloway, by James IV, the Scottish king. This man made a pair of large wings, which were carefully constructed and covered with a gorgeous array of all sorts of plumage. He announced that at a certain time he was going to fly from the walls of Stirling Castle in Scotland to far-away France.

At the time appointed for the daring priest's hop-off, the castle was surrounded by a throng of spectators as curious as those who now throng to Le Bourget field each time an American aviator is expected to arrive. With his wings firmly strapped to his arms, he made several vigorous flaps and confidently stepped from the castle wall. Instead of taking gracefully to the air, as he had expected, he fell in a heap at the foot of the wall with nothing but a broken thigh bone for his efforts.

Had this alchemist followed the commonsense practice of a modern inventor, he would have tried out his wings privately before the day set for his public exhibition. If he had made a trial flight of a more modest nature, he might have saved himself much physical pain and mental embarrassment. He found no difficulty, however, in explaining his failure to his own satisfaction as well as to that of most of the people of his time. He said that, unhappily, some of the feathers of his wings were those of barnyard fowls. These feathers were, he believed, attracted to the barnyard, whereas had they been those of eagles alone, they would have taken to the air naturally enough.

Before any other daring inventor got around to trying out wings covered entirely with eagles' feathers, however, Borelli, an Italian scientist, proved that man could never fly by his

own strength. He showed that the human body is too heavy, and the muscles of the shoulders and arms too weak, to permit human beings to imitate the method of travel of the birds. Later scientists have shown that the light weight of birds in comparison with their size is because their bones are hollow instead of being filled with marrow, as ours are. Birds adapted for making long flights also have air sacs in their bodies, which increase the amount of air displacement without materially adding to their weight.

THE MONTGOLFIER BROTHERS

Although scientists plainly proved that man can never turn himself into a bird by the use of artificial wings, they could not put out of people's minds the desire to fly. More than two hundred years after the priest's unfortunate experience at Stirling Castle, two French brothers, Joseph and Jacques Montgolfier, wealthy paper makers of a town not far from Lyons, had another inspiration which led to happier results. They had noticed that clouds floated in the air, and they reasoned that vapors similar in appearance to clouds might be harnessed and used by man to satisfy his desire to fly. They believed that white smoke inclosed in a lightweight bag might float in the air. Consequently, near the end of 1782, they filled some large paper bags with smoke from a fire built underneath them, and were overjoyed to find that they actually rose.

After the success of their experiments with paper bags, the Montgolfier brothers made a large linen bag 33 feet in diameter, lined inside and out with paper. When this was finished, they invited all the people from round about, including many state officials and persons of note, to attend a public trial of their balloon. When all was ready for the experiment, a fire, fed with chopped straw, was built under the balloon, and the inflation required only a few minutes. To the astonishment

of all witnesses, the bag rose quickly, floated in the air for ten minutes, and descended at a distance of one and one-half miles from its starting point. This flight marked the real discovery of the balloon.

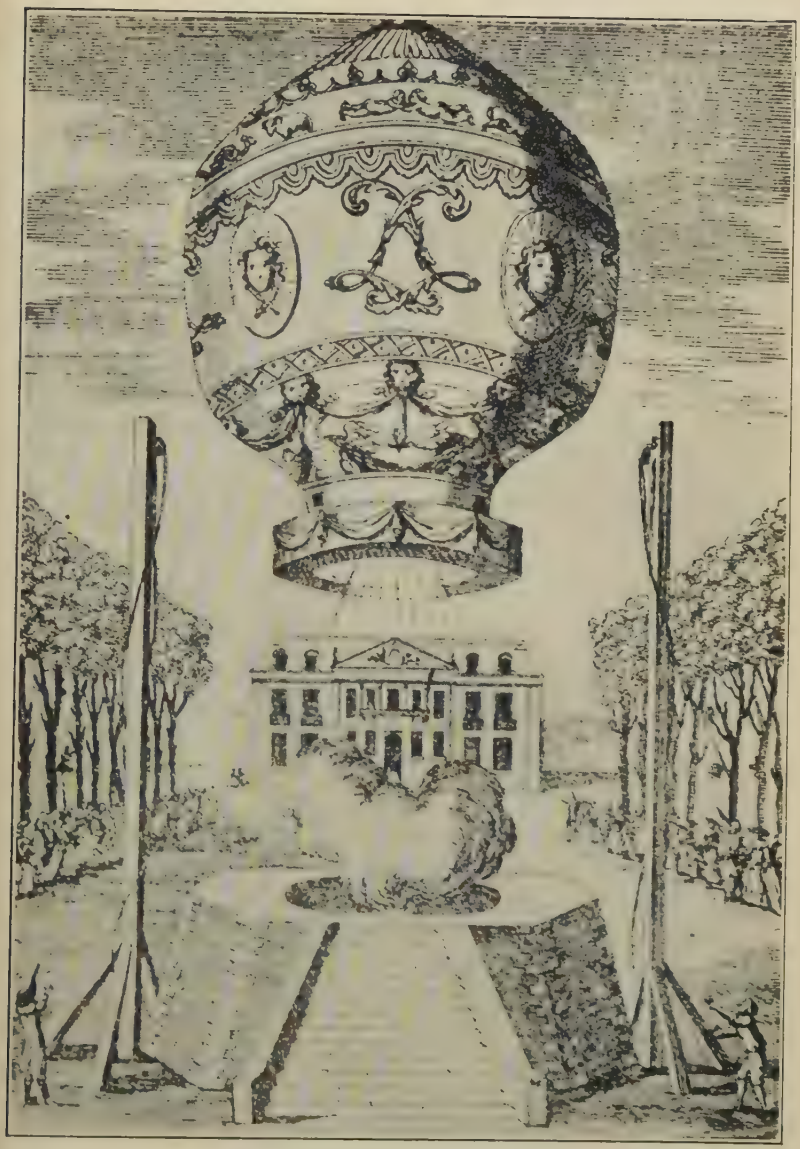
The Montgolfier brothers believed at the time of their first balloon demonstration that their bag rose because of the light weight of the enclosed smoke. It was not until some time later, however, that they came to know that the real lifting power was due to the fact that heated air is lighter than an equal volume of air at ordinary temperatures.

THE FIRST BALLOON ASCENSION

In September, 1783, the Montgolfier balloon ascension was repeated on the palace grounds at Versailles in the presence of the king, queen, court, and a large number of other spectators. The balloon used was similar to the first one, except that it was larger and was ornamented with gorgeous painted designs and trimmings all over its exterior. The inventors placed a sheep, a cock, and a duck in a cage suspended beneath the balloon. The balloon rose to a height of 1,500 feet, and came to earth after eight minutes at a distance of more than a mile from the palace grounds. Except for the fact that the cock was injured by a kick from the sheep, the first aerial navigators were quite unharmed by their unusual experience.

The first human being to ascend in a balloon was a Frenchman named De Rozier. During the same year that the Montgolfier brothers gave their exhibition, De Rozier made several ascensions in "captive" balloons—that is, balloons held fast by long ropes—owned by the inventors.

When it was discovered that heated air was really the lifting agent in the balloons of the Montgolfiers, the inventors knew why their devices descended after a flight of only ten minutes or so. They thereupon constructed a balloon in which the fire was built, not on the ground, but on a platform beneath the



MONTGOLFIER'S GAS BALLOON

The ascent of the balloon before the Palace of Versailles. Although it sailed without passengers, it demonstrated the fact that objects could be made to float in the air and opened up a new field of investigation.

bag of the balloon, so that the air could be kept warm as long as the fire was fed.

Not long after De Rozier first trusted himself to a captive balloon, he and a French nobleman, the Marquis d'Arlandes, were the first to go up in a "free" balloon (one not attached by ropes). The balloon they used was one that carried a fire with it. They circled over the city of Paris and remained in the air something over twenty minutes. They were then forced to descend, because the fire threatened to burn their balloon.

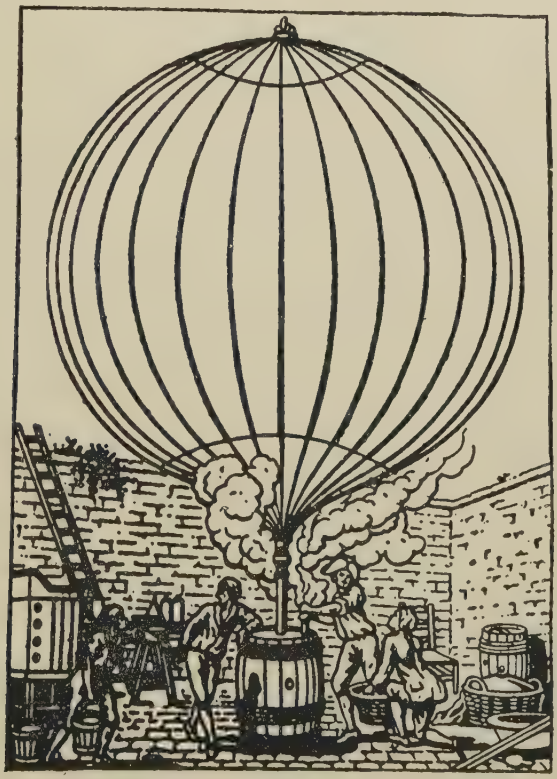
The French people were greatly impressed by the success of the Montgolfier hot-air balloons, and the successful exhibition of their ability to carry passengers. Scientists thereupon conferred honors upon these inventors, and the king gave them high official recognition.

HYDROGEN-FILLED BALLOONS

While the Montgolfier brothers were attracting much attention with their hot-air or so-called fire balloons, another pair of French brothers were working on a balloon of another type. These were the brothers Robert, and they were supervised in their work by the scientist, J. A. C. Charles. This trio proposed to fill balloons with hydrogen, a gas fourteen times lighter than air. They prepared this gas by pouring sulphuric acid on iron filings, and filled a small, varnished silk, trial balloon with it. They sent this up without passengers, and it fell in a field about fifteen miles from the place where it was sent up, greatly startling the peasants who were at work in the field. They believed that this was some agent of the devil, and they attacked it with rakes, hoes, and whatever else they could pick up and tore it into shreds.

Less than a month after Paris had witnessed the flight of the first Montgolfier balloon that carried passengers, the Robert brothers staged an exhibition of one of their hydrogen balloons

in the same city. So popular had the Montgolfier brothers become that people were inclined to have little faith in the new inventors; but these men had the inspiration to send up a hot-air balloon to act as a wind indicator before launching their hydrogen balloon, which action served to show their audience



CHARLES'S HYDROGEN-FILLED BALLOON

that they could master both devices. It is said that so little jealousy was felt by the Montgolfier brothers for these new inventors that one of them actually assisted in the sailing of the first hydrogen balloon.

The Robert brothers' exhibition balloon consisted of a silk sphere varnished with a solution of rubber. The balloon was

13 feet in diameter, and three days were required to fill it with hydrogen. Before these three days were over, people were worked up to a high degree of enthusiasm, and larger and larger crowds came to watch the sight. When the balloon was finally filled, Charles, the scientist, went up as the only passenger. All Paris was thrilled by the success of this voyage, and hydrogen balloons were admitted to be better than hot-air ones.

When the news of the balloon experiments of the Montgolfier and the Robert brothers spread over Europe and the American States, people generally were slow to believe the truth of the reports. Particularly in England were scientists skeptical. When repeated reports convinced the majority that there must be some foundation for the tales told, few people could see that any practical use could ever be made of such a device. Benjamin Franklin when asked his views as to the possibility of balloons ever being of any use, answered, "Of what use is a new-born infant?"

USES OF BALLOONS

The French, however, were not long in showing what use they expected to make of their new invention. When, during the years 1793 to 1797, the young French Republic was striving single-handed against the combined forces of most of Europe, hydrogen-filled silk balloons were used for reconnoitering by all of the divisions of the French army. The decisive victory which General Jourdan gained over the Austrians in 1794 was said to have been the result of the accurate information concerning the enemy's movements which was communicated to him by telegraphic signals from a balloon. This practical demonstration of their military value caused many of the nations of the world to build balloons as a part of their military equipment. In 1808 Alfred Damon Runyon, an American poet, believing that balloons would put

an end to war, published a poem in the *Century Magazine,* in which he expressed his views. A part of the poem follows:

With a dynamite bomb in me hand,
A-sailin' the deep blue sky,
You'll reckon with me on land or on sea,
Some time in the sweet bye and bye.

With a dynamite bomb in me hand
A-shoutin' ahoy to the moon,
A dinky valve-stop 'twixt a thousand foot drop,
In a baggy ole war balloon.

With a dynamite bomb in me hand
Oh pity the earth an' the sea!
I open me hand and there won't be no land,
An' mebbe there won't be no sea.

With a dynamite bomb in me hand
I'm watchin' the shiftin' scenes;
I grin at the crowds, an' the drippy ole clouds
Make a path for the sky-marines.

With a dynamite bomb in me hand,
I'm a-watchin' the quiet increase;
I'm a regular dove a-floatin' above
An' argyin' strongly for peace.

Although balloons have not yet brought about the state of peace which this poet prophesied, they have at least found many peace-time uses. The first use of this sort was that of mere pleasure riding. Those who have experienced this kind of sport say that there is nothing more thrilling than to fly through space and to feel the joy of motion without sound and without effort.

The simplest of all pleasure balloons is the old-fashioned hot-air balloon, in which the parachute performer of the country fair circuit still disports himself for the amusement of the thrilled onlookers. A balloon of this sort is the same type as the Montgolfiers' first model. It is inflated with hot air, and ascends for a few minutes until the air begins to cool off. When further rising is impossible, the performer cuts loose his

parachute and descends into some field or other a mile or so from the fair grounds. The balloon also comes down somewhere near the place where the passenger lands.

The delicately constructed silk hydrogen-filled balloon which was much in use for pleasure riding from about 1900 until 1910 was much more elaborate than the primitive hot-air balloon. During this period, aëro clubs became quite common, and ballooning was as popular a sport as motoring is at the present time. An aëro club was established in Rome in 1904 by no less a personage than Her Majesty Queen Margherita. Many royal persons and other people of note went yachting among the clouds as a pastime about this time. Balloon races of a national and international character became annual events, and some of these are still held.

One of the first practical uses of the balloon was that of exploring weather conditions at high altitudes. At first, balloons were sent up with passengers who carried thermometers, barometers, and other instruments needed in the study of weather. The higher one ascends above the surface of the earth, however, the more difficult it is to breathe. This, together with the great coldness experienced at high elevations, caused several early weather scientists to lose their lives when their balloons reached extreme heights.

At the present time, recording instruments have been perfected which make it unnecessary to send up men with the balloons used to investigate weather conditions at great heights. The balloons which carry these devices consist of rubber spheres filled with hydrogen. If they are allowed to ascend no more than a mile or so, they are held captive by fine piano wires, and are allowed to rise or are drawn in by an engine-driven windlass, which is located in the station. If great heights are to be investigated, however, the balloon is set free. The higher the balloon goes, the thinner becomes the air, and the less pressure is exerted on the balloon. The hydrogen inside the balloon therefore expands. The balloon

will finally reach such a height that the expansion of the gas bursts the envelope, and the cage containing the instruments comes to earth. There are two methods used to prevent damage to instruments when they come down. One is by attaching a parachute between the balloon and the cage carrying the instruments; the other is by using two balloons of about the same size, which are attached to each other, one above the other. Since it is extremely unlikely that both of them will burst at the same instant, they rise until one of them is no longer able to withstand the increasing pressure of the hydrogen within it. When it breaks, the other begins gradually to descend and to carry the instruments with it. A card attached to the cage of instruments tells the finder exactly how and where to send them. With balloons arranged in this way, an elevation of 20 miles has been reached.

Besides its use for pleasure riding and for studying weather science, the balloon has been suggested for other peace-time activities. It has been shown by investigators that captive balloons can be used to prevent hail. Balloons used for this purpose carry guns which explode charges of gunpowder into hail clouds and thus cause them to be dispersed. Captive balloons have also been used to assist in making talking pictures. If a studio is filming a talkie, a captive balloon of a conspicuous color is run up to warn airplanes not to come too near and spoil the sound.

In England, modern balloons have been used to help direct traffic in times of unusual congestion. During recent horse races at Ascot, officers went up in a monster war balloon, from which point they signaled by wireless to officers on the ground when traffic difficulties were threatened.

BALLOONS AND BALLAST

The old-fashioned round balloon was extremely limited in its usefulness because it could not be steered except in very

favorable weather. In good weather these balloons could be guided in one general direction by a very skillful operator, provided the wind played no antics. Their direction had to be managed entirely by changing from one air level to another. While a gentle breeze might be blowing at an elevation of 1,000 feet, a heavy wind in the opposite direction might exist at a higher altitude. If a balloonist of the old type device wished to take advantage of the higher wind, he threw out ballast and rose. Ballast consisted of bags of sand, usually weighing about twenty-five pounds each. The aëronaut carried enough of these bags to see him through any ordinary emergency. If a gradual ascent was desired, he had one open bag from which he could throw out sand a spoonful at a time. If he desired to lower the balloon, he opened a valve which allowed hydrogen to escape in small quantities from the top of the bag.

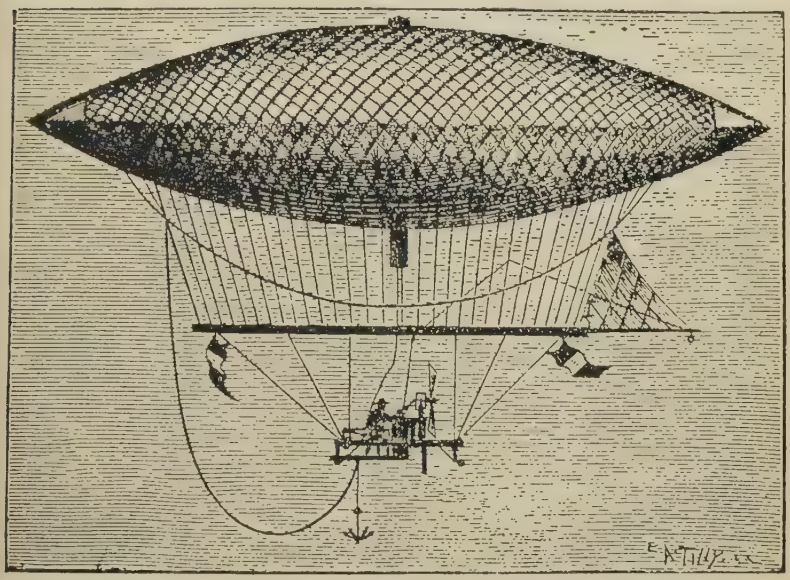
Thus, by raising and lowering the balloon, a voyage in the desired general direction could be made, unless a storm was encountered. In that event, the old-time balloonist usually tried to rise until he was above the storm area. If his ballast was exhausted before this was accomplished, he was obliged to land by opening the valve and letting out hydrogen. In order that the descent might be as gradual as possible, he threw out ballast a little at a time to break the fall. If his ballast was used up, he threw out cushions, fixtures, or whatever he could detach. The chief dread of a pilot of a balloon was that he might be forced to descend into a body of water.

DIRIGIBLES

At the present time, the wind-blown balloon has been largely replaced by airships that can be steered. Airships that can be propelled regardless of the wind are called dirigibles, from the Latin verb *dirigere,* meaning "to direct." Dirigibility or steerableness has been the dream of aëronauts since the time of the Montgolfiers' first ascension. Dirigibility requires some

method of locomotion. One man vainly tried to get this with oars, but he found that air was different from water and that it refused to answer to this kind of treatment. Another inventor, in all seriousness, drew up elaborate plans for hitching a large flock of birds to a balloon, but he never reached the point of trying out his plan in actual practice.

A later inventor tried to use a steam engine for propelling a



ONE OF THE FIRST DIRIGIBLES

This cigar-shaped bag was a great improvement over the balloon because it sailed under its own power and could be steered in any direction.

balloon, but he found that any engine powerful enough to propel the balloon was too heavy for the balloon to carry. In the latter part of the nineteenth century, Samuel Archer King, a famous American aëronaut and scientist, made the following pessimistic statement: "Ever since I became thoroughly acquainted with the characteristics of the balloon, I have been steadily convinced of the absurdity of attempting to control its horizontal motion."

King had no sooner written this, however, when the French government built a successful airship driven by an electric motor. Although it had many glaring defects, it demonstrated beyond the shadow of a doubt that balloons could be propelled. This airship was built in the shape of a cigar, since it was recognized that the bag must be elongated so that it would meet less air resistance. With this device, two French officers were able to make 14 miles an hour and to return five times out of seven to their exact starting point. On windy days, however, its engines were too weak to propel it against the wind.

SANTOS-DUMONT

Meanwhile, about 1895, a young Brazilian named Santos-Dumont appeared in Paris and proceeded to astonish the world with his feats. He was a man of wealth, and he also had courage and perseverance. He constructed fourteen airships altogether, all of which made more or less successful flights. During some of his trips he landed in trees, in the water, and on the roofs of houses, but he always had the presence of mind to escape safely.

One of Santos-Dumont's first airships was so small that he could fold it up and take it home in a valise after a flight. Although he found it necessary to increase the size of his ships, he continued to strive to keep them as small as possible. In order to do this he was obliged to find a lightweight engine of greater power than any that had been previously used. One day, while admiring the simplicity of the gasoline motor on his motor-tricycle, he decided to work on the problem of adapting the gasoline motor to the airship. This inspiration was an important one. Although the first gasoline engine that he used was certainly a crude affair, the development of lightweight, high-power gasoline motors was not long in coming, for the automobile industry was just then in its infancy. The problem

of power with little weight was consequently solved for both the auto and the airship.

Even after the engine question was solved, Santos-Dumont had other serious difficulties. His cigar-shaped gas bags had the most unseemly habit of crumpling during a flight. Particularly was this true when he was in the act of coming to earth. During a descent, the gas in the bag contracted, and the bag was no longer properly inflated. As a result, it would proceed to fold up in the middle like a pocket knife and to plunge downward in disorder.

After several experiences of this kind, Dumont concluded that it was necessary to stiffen the bag in some manner. This he did in one ship by placing a bamboo rod between the car and the bag. This machine was the most successful one up to that time, and later machines had more and more elaborate arrangements for making the bag non-collapsible.

Although Santos-Dumont never really invented anything new, he succeeded more than any one else of his time in applying other inventions to the particular use of the airship. He succeeded in making the dirigible very popular wherever he went, but he never produced a machine that had a very great speed.

The dirigible which was worked out at this time by various French inventors and by Santos-Dumont was of the semi-rigid type. The semi-rigid dirigible is one in which the bag is kept from folding up in the middle by being attached to a rigid keel.

ZEPPELINS

While French inventors were quietly working on airships which should be suitable for military purposes, and while the Brazilian, Santos-Dumont, was keeping all Paris interested in airships by sailing around the city and parking in the most unexpected places, a German inventor was working on an entirely new kind of dirigible of monstrous proportions. This

Courtesy Wide World Photos

THE GRAF ZEPPELIN

The first airship to circumnavigate the globe is shown here on a flight over Philadelphia.

inventor was none other than Count Ferdinand von Zeppelin.

Count Zeppelin was born in 1838 in Constance, a city of the grand-duchy of Baden. He received a military and scientific education. It is interesting to note that he served as a volunteer with the Union Army during our own Civil War. It was during this experience in America that he made his first trip in a balloon, in Minneapolis. This trip is said to have marked his first interest in air navigation.

After the Count's return to Germany he took an active part in two wars, and retired from the army at the age of fifty-one. After his retirement he spent the remainder of his life putting into practice his pet ideas as to what would be an effective kind of dirigible.

Although Santos-Dumont had striven for small size in airships, Count Zeppelin planned his dirigibles along gigantic proportions. His first airship, completed in 1900, was 410 feet long. Instead of the semi-rigid construction which was used throughout the rest of Europe, Zeppelin made a vessel with lightweight, rigid metal framework surrounding the entire bag. Instead of placing all the gas in this one huge bag, Zeppelin divided the whole into seventeen compartments, into fifteen of which he placed separate hydrogen-filled bags. The entire framework was covered with a strong fabric. A lightweight metal keel gave strength to the whole structure. Two cars were attached directly to the keel, and in each was a 16-horsepower gasoline motor. The motors drove propellers mounted at the sides of the dirigible.

Zeppelin's first airship made its trial flight without suffering the collapse which had been experienced by the first ship of many former inventors. This was the result of the sturdy yet lightweight framework that surrounded the bags. There were also many advantages in having separate bags. The bursting of one or two of the bags of a Zeppelin will not cause collapse.

A further advantage of the use of separate bags is that each bag lies in a compartment lined with canvas, while the whole

metal framework is covered with a stout waterproof fabric. Between the inner and outer layers of fabric is an air space which acts as a heat insulator. The gases inside the bags are therefore protected to some extent against rapid contraction and expansion caused by sudden changes in temperature.

Although Zeppelin's first airship was probably more successful than any of previous inventors, it could make a speed of only little more than 15 miles an hour, and the minor breakdowns that it suffered were numerous. The Count at once set to work to make new leviathans of the air which should have more powerful and reliable engines, a stronger framework, and numerous improvements in methods of control. In 1906 he attained a speed of 30 miles an hour, and in 1907 a speed of 36 miles an hour. At this time Zeppelin wrote for an American journal that he could foresee the day when airships could be used for carrying fifty passengers, reaching the North Pole by easy stages, carrying food, water, and ammunition to troops, and rising above the clouds to observe a solar eclipse.

Before his death in 1917, Count Zeppelin saw many of his predictions come true. Before the beginning of the late war, German dirigibles had made many commercial flights, principally between large German cities, but occasionally across the border to Austria. They had made in all 1,588 trips and had carried 34,228 passengers previous to 1914. During the War they were used also, as the inventor had predicted, as aids to the army, particularly for bombarding enemy towns back of the line of battle.

Many Zeppelins (this name is now properly applied to rigid dirigibles) have met with disastrous ends. A number of the earlier airships made by the inventor were struck by lightning and burned. When, in 1908, Count Zeppelin launched his fourth ship, the trial flight was so successful that all Germany was enthusiastic over its performance. During the flight, however, the Count lowered the ship and anchored it at Stuttgart, Germany. While he and the crew were lunching at a café, an

unexpected storm suddenly arose and beat against the dirigible so strongly that it broke away from its moorings. A number of gas bags were torn, and in some way the hydrogen was ignited and the whole ship was destroyed. Many other Zeppelins have met the unfortunate fate of descending to earth in flames.

THE VULNERABLE POINT IN ZEPPELINS

The point of danger in Zeppelin's airships was the inflammability of hydrogen. When this gas becomes mixed with air, it not only burns, but bursts into flames with explosive violence. In the Zeppelin there is a space between the gas bags and the walls of the compartment in which they are contained. So small are the hydrogen molecules that no fabric, no matter how carefully prepared, can keep some of them from diffusing through its pores. The hydrogen which thus becomes mixed with air in this space constitutes the most dangerous part of the whole structure. The introduction of the tiniest spark from any source will serve to set it off. The failure of German Zeppelins to do more damage than they did to French and English towns during the War (and the results were certainly serious enough) was because of the fact that a single puncture from an incendiary bullet would prove fatal to the airship.

The honor of developing a gas which will not burn and which is sufficiently light in weight to be used in airships belongs to the United States. This gas is helium. The United States Navy is using it exclusively in its larger dirigibles. Helium is second only to hydrogen in weight, having 92 per cent hydrogen's lifting power. It is superior to hydrogen in being non-inflammable.

THE "LOS ANGELES"

The *Los Angeles*, one of the most interesting of the American naval airships, uses helium exclusively as its buoyant gas. This ship was built for the United States at the Zeppelin plant

in Friederichshafen in Southern Germany. According to the treaty of Versailles, all of Germany's aircraft was to be divided among the Allies. Because some over-patriotic German citizens destroyed the two small ships that the United States was to receive, the German government asked permission to build a large passenger ship as a substitute.

The *Los Angeles* left Germany on the 432nd anniversary of the discovery of America. A daughter of Count Zeppelin was among those who witnessed the launching of this, the 126th rigid airship built in her late father's plant. The *Los Angeles* made its trip filled with hydrogen, but the gas was changed to helium after its arrival here.

THE "SHENANDOAH" TRAGEDY

When the *Los Angeles* came from Germany to America, it joined the *Shenandoah,* another American airship, at the airport at Lakehurst, New Jersey. The *Shenandoah* was built here along the lines of the German dirigibles. Whereas the *Los Angeles* was built to serve as a passenger airship exclusively—to carry, as one writer expressed it, tourists, traveling men, babies, and suitcases—the *Shenandoah* was built as a military craft.

The tragedy that befell the *Shenandoah* is well known to all of us. This pride of the United States Navy was caught in a severe storm September 3, 1925, near Caldwell, Ohio, while it was crossing the country to attend some state fairs. The craft was broken into two parts, and fourteen of the crew were lost. Thirty-three of the men were saved, however, nine of them floating to safety on a portion of the helium-filled ship, which sailed a distance of 12 miles like a free balloon before coming to earth. The remainder of those saved likewise floated to earth in the main portion of the ship. Those who were killed were in the control cabin, which became detached from the ship during the tornado.

The *Shenandoah* disaster demonstrated beyond a doubt the value of helium in a situation of this sort. Had the ship been filled with hydrogen instead of helium, it would have ignited and added fire to the rest of the disaster.

DISCOVERY OF HELIUM

The element helium has been known only a short time. Its discovery marks one of the most notable events in man's mastery of stuff.

On August 18, 1868, a notable eclipse of the sun was visible in India. Astronomers from all over the world had journeyed there to see it. Among these was a French astronomer named Janssen. The spectroscope was a new instrument at that time, and many of the astronomers used it to study the substances that compose the atmosphere of the sun. (Each substance, when heated, absorbs different wave lengths of light and gives a peculiar spectrum through this optical instrument.) All of the investigators agreed that the spectrum of hydrogen was easily visible. Janssen found still other spectral lines which failed to correspond with those of any element yet known. So bright were these lines that he repeated his spectroscopic examination of the sun the day following the eclipse, and found that the lines were still visible. When Janssen communicated his find to others, Sir Norman Lockyer, of England, confirmed his report and satisfied himself that the sun had shown evidences of possessing an element hitherto unknown. Lockyer therefor named this new element *helium,* after the Greek word for sun.

Some babies are named before birth; and so was helium named before its discovery on earth. "Found originally in the sun, 90,000,000 miles away; traced to the stars, thousands of times as far away as the sun; over a quarter of a century elapsed before it was found upon the earth," wrote C. G. Abbot in the Smithsonian Institution report of 1918.

CHARACTERISTICS OF HELIUM

A study of the characteristics of helium showed it to be a colorless gas without taste or odor. It proved to be non-combustible and inert chemically. Despite the greatest efforts on the part of chemists, helium has never been made to unite chemically with any other known substance. While hydrogen will liquefy at −234.5 degrees centigrade or −454.1 degrees Fahrenheit, helium will not liquefy until a temperature of −268 degrees centigrade or −514.4 degrees Fahrenheit has been reached. Even at this low temperature, a pressure of 20 atmospheres is required to reduce it to the liquid state.

HELIUM AND THE WAR

When, during the last war, scientists of the United States were confronted with the problem of trying to surpass the Germans in aërial warfare, one of their chief thoughts was to find a non-combustible substitute for hydrogen, inasmuch as the hydrogen-filled airship could no longer be of ideal value because of the perfection of the incendiary bullet. Helium was indeed desirable, but from 1895 until that time there had been produced only a little more than 100 cubic feet of it—scarcely enough to fill a single compartment of a modern dirigible. Expense, too, was a great factor, for this gas cost $2,500 for the production of one cubic foot. Hydrogen, on the other hand, cost only $11 per thousand cubic feet.

In face of this need, some one in the Navy Department dug up from some forgotten file the information that helium was contained in small amounts in the natural gas of a certain region of the southwestern United States. This set scientists to thinking, with the result that they began testing samples from every large gas field in the country to find out if helium were present. The gas from the district around Fort Worth and Petrolia was found to contain from .3 to 2.5 per cent

helium. Professor Hamilton P. Cady of the Chemistry Department of the University of Kansas discovered that Kansas natural gas contained nearly 2 per cent of helium, but the Texas fields seemed the most promising as a commercial source, since the natural gas supplies were much larger there.

The government decided to take up this project, and accordingly it made appropriations for the purpose. Three plants were built in Texas, two at Fort Worth and one at Petrolia. Three processes were available for commercial production: the Linde process, devised by a German chemist of that name; the Claude process, devised by a French chemist of that name; and the Jeffries-Norton process, devised by two American chemists, Jeffries and Norton. Number 1 plant at Fort Worth uses the Linde process; Number 2 plant at Fort Worth uses the Claude process; and Number 3 plant at Petrolia uses the Jeffries-Norton process.

The latter process is the most important of the three. In this process, the natural gas is liquefied by reducing the temperature to −268 degrees centigrade or below, and by using a pressure of at least 20 atmospheres. This liquefied gas is then placed in a container in which a slightly lowered pressure permits it to simulate the physical movement of boiling water. Helium, the lightest constituent, will be volatilized before any of the other gases. It is then collected and stored in flasks.

Now that helium can be produced in large enough quantities to make helium dirigibles and balloons possible, the use of this gas has increased greatly. It is easy to realize why helium is preferable to hydrogen when one considers the difference in risk in the use of the two gases.

HELIUM IN NATURAL GAS

The way that helium came to be found in some natural gases is interestingly told in an article written by G. Sherburne Rogers in the *National Geographic Magazine:*

In 1903, a well was drilled in the little village of Dexter, in Southern Kansas, and a great flow of natural gas was encountered. The nearest gas field at that time lay a considerable distance to the east, and the owner of the well, having visions of Dexter becoming a great manufacturing center, invited the countryside to assemble and celebrate the event.

On the day appointed and in the presence of a goodly crowd, the well was opened and the gas allowed to roar forth; whereupon, in order to make the demonstration dramatically complete, a lighted torch was thrust into the gas—and the torch promptly went out. Several more attempts were made, but the gas absolutely refused to burn. Gloom descended on the assemblage, and the visions of cheap fuel and manufacturing wealth went glimmering.

A sample of the gas was sent to the University of Kansas for analysis, and the secret of its fireproof qualities was at once revealed, for it was found to contain only about 14 per cent of the combustible hydrocarbons which ordinarily make up natural gas, and to consist for the most part of nitrogen.

As nothing like this has been discovered before, Professor H. P. Cady, of the University of Kansas, examined this inert portion of the gas further and finally discovered helium in it.

HELIUM AND THE FUTURE

Dr. R. B. Moore, Dean of Science at Purdue University and formerly connected with the Bureau of Mines of the United States Government, speaking on the subject of helium before the Institute of Chemistry held at the Pennsylvania State College, July, 1927, spoke confidently of the future of helium. He said, in part:

Helium can be purified readily after it has been used in an airship. Repurification cannot be carried out with hydrogen on account of the danger, and, therefore, the actual cost of helium is very little more, if any, than that of hydrogen for aëronautical purposes. Most people do not realize the commercial possibilities of airships filled with helium, owing to the fact that a number of accidents have happened to airships since the war. They forget that the first steel ships broke in two and that practically all of the early airplanes crashed. The development of airships to-day is in about the same

stage as the development of airplanes was at the beginning of the war. In order to learn just what changes should be made in design and construction, and what stresses an airship actually has to undergo in service, it is necessary to build airships even though a few of them are destroyed. The knowledge so obtained makes the next ship constructed safer and better. If the United States Government were to construct ten airships at intervals of one year at an approximate cost of $4,000,000 each, the results obtained would undoubtedly make airships one of the most important methods of transportation of the present day. Helium makes this possible, as it removes practically all danger of fire.

For war purposes, helium-filled airships are the very best scouting means that the Navy can use. During the World War the British Admiralty estimated that one airship was the equivalent of six fast scouting cruisers for scouting purposes. A 6,000,000 cubic foot airship with a speed of 75 miles per hour costs less than $4,000,000. A fast scouting cruiser to-day costs $10,000,000, so that the relative initial cost would be $4,000,000 against $60,000,000. Operating costs would also be greatly less.

There is no doubt but that discoveries of new sources of helium or improved methods of extracting it will make it possible to produce large quantities of this gas for use in everyday commercial air navigation. When airship travel becomes a regular and established thing, a newer interest in such sciences as geography and geology will be developed; Red Cross dirigibles will be equipped for rescue work in time of great disasters; hospital airships for treatment of patients suffering from lung trouble will be maintained; places of interest heretofore inaccessible will be opened up; and above all, all the people of the world will become better acquainted with each other, because no city in the world will be further than ten or twelve days' travel from any other city.

Thus the perseverance and ingenuity of man has not only made the rivers and oceans servant to the human will, but has mastered the navigation of the air as well. Safe voyages in lighter-than-air craft are made possible by the discovery of helium, a non-inflammable, lighter-than-air gas. This gas is

new only so far as our knowledge of it is concerned, however, for it was present in the time of the Egyptian prince and princess, Rahotep and Nefert, although they knew nothing about it. It remained for American chemists of our own day to discover how to obtain this hitherto rare material, and thus make it possible to hitch our wagon to a gas bag without danger of being burned to death.

CHAPTER XIX

THE LIGHTWEIGHT CHAMPION OF THE METALS

"You're rather young," said Dædalus, "to tempt the upper air;
But take the wings, and mind your eye, with very special care;
And keep at least a thousand miles below the nearest star,—
Young lads when out upon a lark, are apt to go too far."

—John G. Saxe

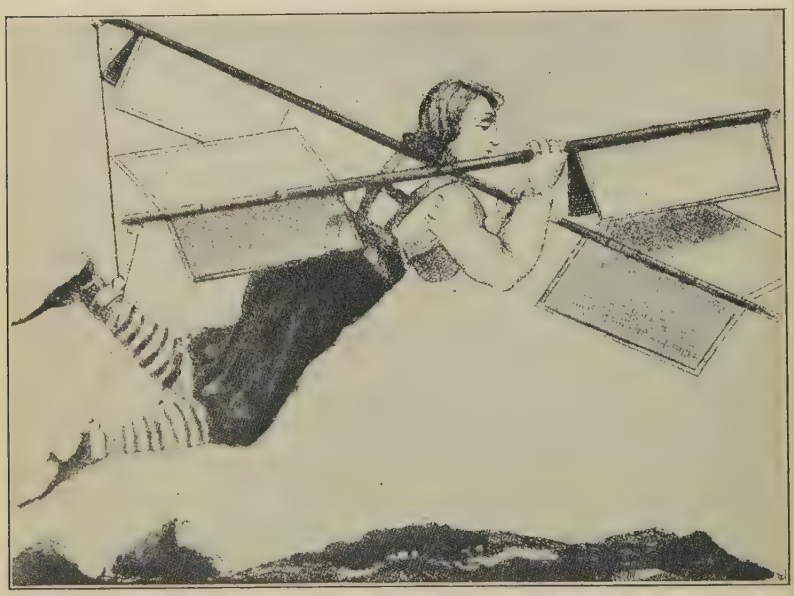
An ancient Greek myth tells of Dædalus and his son Icarus, who were trying to escape from the island of Crete because they had incurred the disfavor of King Minos. They succeeded in escaping from the tower in which they were confined, but were unable to leave the island because the king had placed special guards at every port to search all outgoing vessels. Finally it occurred to Dædalus, according to the myth, that Minos might control the land and the sea, but he did not have power over the air. Thereupon he made wings for himself and his son, which enabled both of them to fly. His son, however, in spite of his father's warnings, became quite bold when he felt his own strength. As a result, he soared too high, and the sun melted the wax that held the feathered wings together and in place. When his wings were ruined, the unfortunate lad fell into the Ægean Sea and lost his life.

IMITATORS OF DÆDALUS

Many people of all times have tried to put the ancient fable about Dædalus and Icarus into actual practice, and, in spite of the misfortunes of many who had tried unsuccessfully to master the air with wings, the opening of the twentieth century still found the idea of flying no less alluring than it has always been. Balloons, of course, had already made air travel

quite commonplace. Floating through the air, however, did not have quite the appeal of adventure, the speed, or the adaptability which men hoped to achieve with a device that actually had wings.

Otto Lilienthal, a German, gave remarkable gliding demonstrations about the beginning of the century, which gave scien-



THE FIRST SUCCESSFUL FLIGHT

Besnier, a French locksmith, glided with this device from the garret of a house, over a nearby cottage, and landed safely on the ground. This flight was made in 1646.

tists the notion that a device with wings might travel some distance if an engine were added to stir up artificial breezes. The first airplane of this sort to be built on a large scale was that of Hiram Maxim, an Englishman. Maxim tried to launch a plane in 1894, and achieved enough success to prove that a heavier-than-air device could be lifted from the ground by its own propelling force. His plane was a bulky device, with a wing spread of 150 feet and a weight of 8 tons. It was pro-

pelled by a steam engine which burned oil. He set this machine on a short railroad track. A second pair of rails was built above the first. The purpose of the second set of rails was probably to keep the plane from leaving the ground too suddenly. When the engines were started, the plane not only rose from the lower rail and ran along clinging to the upper one, but it exerted such an upward pressure that it tore off a

A NINETEENTH-CENTURY ATTEMPT TO FLY

Otto Lilienthal captivated the world from 1891 to 1896 with his glider. He took off from the edge of a cliff and maintained flight by means of air pressure beneath the 172 square feet of his wing surface. He was killed in a flight after he had added a compressed carbon dioxide engine to his flying device.

part of the upper track. The wreckage became entangled in one of the sails, and the plane was wrecked.

About the same time that Maxim built his airplane, Professor S. P. Langley, Secretary of the Smithsonian Institution, began experiments with working models of airplanes not designed to carry passengers. One of these, equipped with a small steam engine, made a flight of half a mile down the Potomac River in 1896. Professor Langley thereupon built a passenger plane much smaller in size and better in design

than Maxim's device. This plane made two attempts at flight in October and December of 1903, but was damaged in both instances during the take-off. The first flight of an airplane bearing a passenger was made by Wilbur Wright on December 16, 1903, at which time he flew for 59 minutes in a plane built by himself and his brother Orville. The memorable flight took place at Kitty Hawk, North Carolina, and was followed the next day by a series of equally successful trips. The Wright success was due to their invention of a forward rudder and the introduction of a gasoline motor.

ALUMINUM AND AVIATION

Many factors have contributed to recent progress in aviation, not the least of which has been the development of the aluminum industry.

Aluminum, a substance as white as silver, as easily melted as copper, as unaffected by the weather as gold, and yet lighter in weight than any of these, is nature's most abundant metal. All of us trample it under our feet every day. It is one of the main constituents of common clay, and is found in all rocks except sandstone and limestone. In clay and rocks it is chemically combined with a number of other elements, from which it is not easily induced to part company. If it were possible to smelt clay and rocks in the same manner that copper and iron ores are smelted, the secret of its existence would have been stumbled upon early in the history of the human race. It was not until 1828, however, that a German chemist named Friederich Woehler prepared, by a very tedious and roundabout method, the first tiny bit of aluminum ever known. A few years later, a small bar of this new and rare silvery-white metal was exhibited as a curiosity at a universal exposition, in which products gathered from the four corners of the earth were on display. It attracted a great deal of attention at the time.

AN EMPEROR FOSTERS RESEARCH

About 1854, Napoleon III became interested in aluminum because of its light weight. He thought that this metal might be used to diminish the weight of the helmets and armor of the French guards. He consequently gave a government donation to Henri Deville, one of the greatest French chemists of the day, for the establishment of an aluminum factory. He thought that Deville could manufacture jewelry and other small articles of aluminum and sell them to pay the expenses of running the factory. At the same time, he expected the chemist to try to find a cheaper method of production.

As a result of the emperor's gift, Deville established an aluminum factory, and the first article that he turned out was a baby's rattle for the young Prince Imperial. For thirty-four years thereafter he continued to extract about 5,000 pounds of aluminum a year. He turned almost every bit of this into rings, brooches, thimbles, and other small fancy articles which he sold for high prices. During this same period, Deville and many others of the best chemists of the time exerted themselves to find a cheap method of producing aluminum. Woehler's original method was changed only slightly through the combined efforts of all of them. By finding out how to produce somewhat more cheaply the materials used in this process, the price of aluminum was brought down from $160 a pound in 1828 to $12 in 1886. This reduction was all that could be expected from the old process, however, and the price of aluminum would have prohibited its use for anything except jewelry and small statuary had not a new method of extraction been discovered.

AN AMERICAN INVENTOR

The present cheap price of aluminum is the result of the work of an American boy who was blessed with an unusual

imagination and who was not afraid of work. The name of this boy was Charles Martin Hall, who was born in 1863 and died in 1914. Hall was the son of a clergyman, and from the time he was in the lower grades he read all the books and maga-

CHARLES MARTIN HALL

zines on science he could find. In many of these publications he read of aluminum, a rare metal which looked like silver and platinum. One battered old chemistry textbook, which his father had studied and which had been published in 1841,

told how extensively aluminum was distributed in nature, and yet how difficult it was to obtain it by any method then known.

When Hall entered Oberlin College, he obtained permission from Professor Jewett, the chemistry supervisor, to work at odd times in the chemistry laboratory. Hall's father was a resident of the town of Oberlin. As a boy of twelve, Hall had already made Professor Jewett's acquaintance by coming to the laboratory and buying glass tubing and other bits of equipment.

The study that Hall was working upon was a method of separating aluminum from its compounds by a direct and inexpensive method. Alumina or aluminum oxide was the purest natural compound of aluminum that he could find, and it was with this compound that he made his experiments. Hall knew that aluminum oxide could not be smelted with charcoal or coke in the same way as most common ores, so he wasted no time on this method. He had heard, however, that some metals could be forced to separate from the other elements with which they are chemically combined by means of an electric current. He therefore tried to separate aluminum oxide by electrolysis, and for this purpose gathered together a number of batteries and some apparatus.

A number of difficulties to the scheme soon presented themselves. In the first place, the examples of electrolysis that he had read about required that the compound of the metal be in liquid form. He tried to dissolve aluminum oxide in various solvents, and then to electrolyze it, but without success. He made every effort to melt it, but it stubbornly remained solid. While he was making many unsuccessful experiments, the time for his graduation rolled around.

Hall graduated from Oberlin in the spring of 1885. Not content to give up his experiments with aluminum, he moved his equipment to his father's woodshed and continued at his task. Since aluminum oxide would not melt of its own accord,

he determined to find some fluxing agent which would dissolve the stubborn aluminum ore. This likewise proved a difficult task, but Hall worked on undiscouraged.

In February, 1886, eight months after his graduation, Hall made his great discovery. He found that cryolite, a compound of aluminum, sodium, and fluorine, which came from Greenland, was the solvent for aluminum oxide that he had been searching for. Cryolite could be melted quite easily, and aluminum oxide dissolved in the melted liquid like sugar in boiling water. An electric current passed through the hot solution separated the aluminum oxide into the two elements that composed it. Uncombined aluminum was the result.

At the time that Hall made his discovery, he was using a carbon lined crucible in which he melted and electrolyzed his cryolite-aluminum-oxide mixture. The rest of the apparatus consisted of a stick of graphite, a seven-cell Grove battery, a few pieces of copper wire, and a gasoline-torch. With this simple lay-out, he succeeded in doing what the most noted scientists of the day had tried unsuccessfully to do for more than fifty years, that is, in changing aluminum from a rare metal ranking with silver, gold, and platinum, to a common metal cheap enough for practical everyday purposes.

As soon as Hall made his discovery, he had the usual trials of the young inventor. First he had to convince investors that his process was all that he claimed for it, and then he had to defend his patents in court against impostors. He finally organized a company called the Pittsburgh Reduction Company, which is still in existence under the name of the Aluminum Company of America.

The commercial production of aluminum was begun in 1888. The first plant of Hall's company was built near Pittsburgh. It was not long before the advantages of using water power as a source of electricity caused the company to establish a second plant at Niagara Falls, and to become the first consumers of electric current generated by this extraordinary body

of water. By 1911 this company had three factories, was using 140,000 horsepower of electric current, was turning out 40,000,000 pounds of aluminum a year, and had forced down the price to 22 cents a pound. All of this resulted from a boy working with crude apparatus, but with an idea to which he clung in spite of all sorts of discouragements.

INDEPENDENT DISCOVERY OF ALUMINUM

It is interesting to know that Hall's discovery was made independently by a French youth, Paul Heroult, who did not know that Hall was working on the problem. Hall and Heroult were born the same year. They were both twenty-two years old when they made their discoveries; they made their results public at almost the identical time, and they each received patents in their own countries the same year. American books mention Hall as the discoverer of the present method of preparing aluminum. European books make no mention of Hall, but give all of the credit to Heroult. As a matter of fact, both men deserve the same credit, for both of them worked out the same process at the same time, without either of them knowing anything about the other's work.

A RARE METAL MADE CHEAP

Hall's company now leads the world in the production of aluminum, and has command of the leading aluminum oxide mines of the world. Since aluminum cannot be purified after it is separated from its ores, it must be made from a very pure ore. Bauxite is a native ore which exists of an especially pure form of aluminum oxide. The chief bauxite beds are found in Arkansas, Alabama, Georgia, and Tennessee. The chalky white ore which these mines give up will dissolve in melted cryolite and can then be separated by an electric current and made to yield silvery-white aluminum. Cryolite, once

a natural product found chiefly in Greenland, can now be made artificially.

Aluminum, unknown a century ago, can now be bought in large quantities for a few cents a pound. When copper was first discovered, it remained a rare metal for many centuries. Even iron was once a rare and precious metal, and it remained so for a long period of time. Although the Bronze Age and the Iron Age required hundreds of years for their creation, aluminum came into widespread use less than sixty years after its discovery. Man has shown that he can create a new metallic age within two generations. This is possible because man now knows so much more than he once did about the composition and behavior of materials.

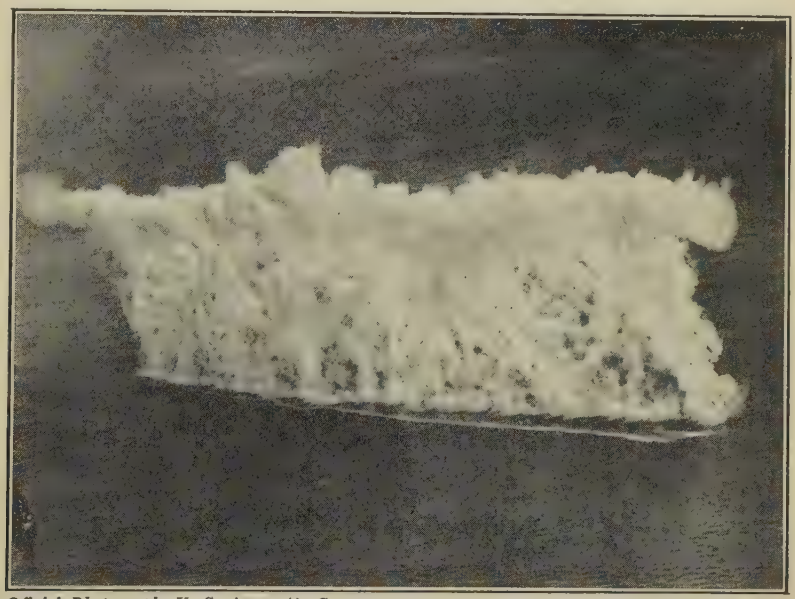
Chemistry, or the science of materials, has had much to do with the adaptation of aluminum to various uses after a cheap method of extracting it from its ores had been discovered. The chemist has found that a bronze, similar in appearance to gold and suitable for ornamental purposes, can be obtained from aluminum alloyed with 85 to 95 per cent copper. With 2 per cent of magnesium, he has produced a very hard alloy that can be turned on a lathe and used to make machinery parts. This alloy is called magnalium. The chemist has also found out what first seemed to be an impossibility, namely, how to solder and weld aluminum. The knowledge of alloying, soldering, and welding this metal established its use for many purposes.

ALUMINUM ALLOYS IN AVIATION

It was early recognized that aluminum, because of its light weight, was valuable for making parts of airplanes. Aluminum, either as pure metal or in one of its alloys, constituted one-third the weight of the Liberty motor, which has played such an important part in the recent achievements of the United States Army Air Service.

One alloy of aluminum that is quite important in the manu-

facture of aircraft is composed of 96.25 per cent aluminum, 3 per cent copper, .5 per cent magnesium, and .25 per cent silicon. Other aluminum alloys are fast coming into use for special purposes in this field. Pure aluminum is not suitable for many purposes because of its lack of strength. Aluminum alloys, however, can be made to have the strength of mild



Official Photograph, U. S. Army Air Corps.

A SMOKE SCREEN DROPPED BY AN ARMY AIRPLANE

A considerable number of ships can hide behind this screen.

steel, and still be only one-third as heavy. These alloys, therefore, are ideal for uses that demand lightness of weight combined with strength and toughness.

DURAL AND ALCLAD

Recently, aviators have attained speeds with airplanes that would challenge the average bullet. The original Wright plane had to exert itself to produce 40 miles an hour. These differ-

ences in speeds lie in the refinement of each separate detail of the modern plane. While the Wright brothers obtained 40 horsepower with their first engine, which weighed nearly 200 pounds, the engine of the modern racer develops 500 horsepower and weighs under 700 pounds. The propeller of the modern racer is not a wooden blade, as was formerly used, but a thin aluminum alloy forging. By the use of these alloys wherever possible throughout other parts of the plane, the weight of the entire structure is reduced to a minimum, and low weight per horsepower is secured.

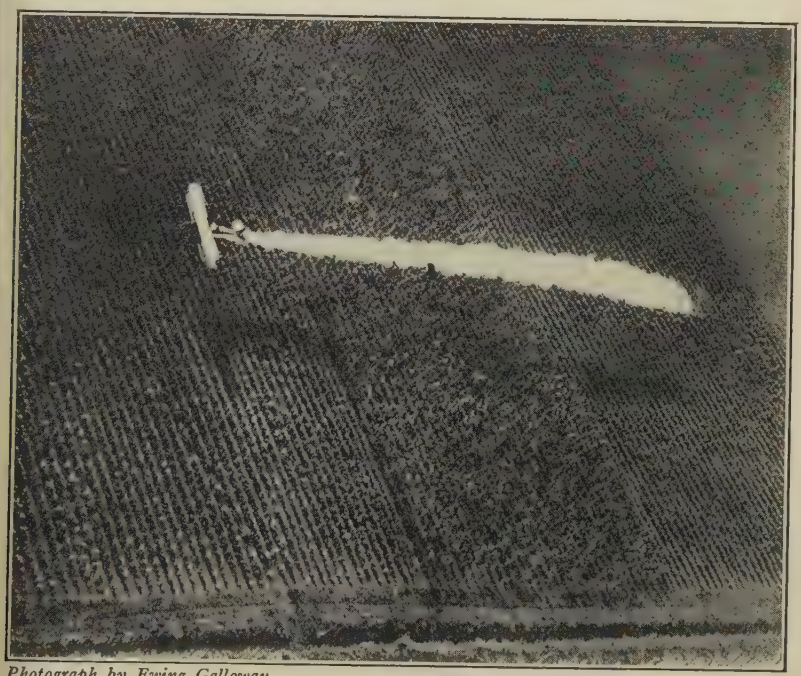
PEACE-TIME USES OF AIRPLANES

With the refinement of airplanes, they promise to be very useful, not only in warfare, but for peace-time activities as well. Not long ago, a number of army airplanes were used to suppress serious forest fires in this country. These planes acted as scouts and gave directions for controlling the fire, from the ground, which would not have been possible without their use.

Airplanes have been used effectively in exterminating insect pests. For example, in 1922 a grove of catalpa trees near Troy, Ohio, was nearly stripped of its leaves by caterpillars. This grove was not only being ruined, but there was danger that other trees for miles around would be infested. An airplane was called in. The aviator flew over the grove and scattered a cloud of lead arsenate from a hopper attached to his plane. This poison exterminated the pests. The airplane thus accomplished in one minute what twenty of the most powerful liquid-spraying machines, operated from the ground, could not have done in twenty times as long. Many orchard owners have since hired airplane owners to do their dusting.

Among other peace-time activities of the airplane has been its work in the sealing industry. Men following this industry have been handicapped because they found it dangerous to

search in boats for seal-laden drift ice in Arctic waters. The airplane does away with this difficulty by scouting for seals and sending messages to the fleet by wireless. In the Pacific Ocean, fishermen have also used the airplane as a means of scouting for schools of fish, particularly in the tuna fish industry. The aviator in a scouting airplane locates a school of



Photograph by Ewing Galloway

AN AIR ATTACK ON THE BOLL WEEVIL

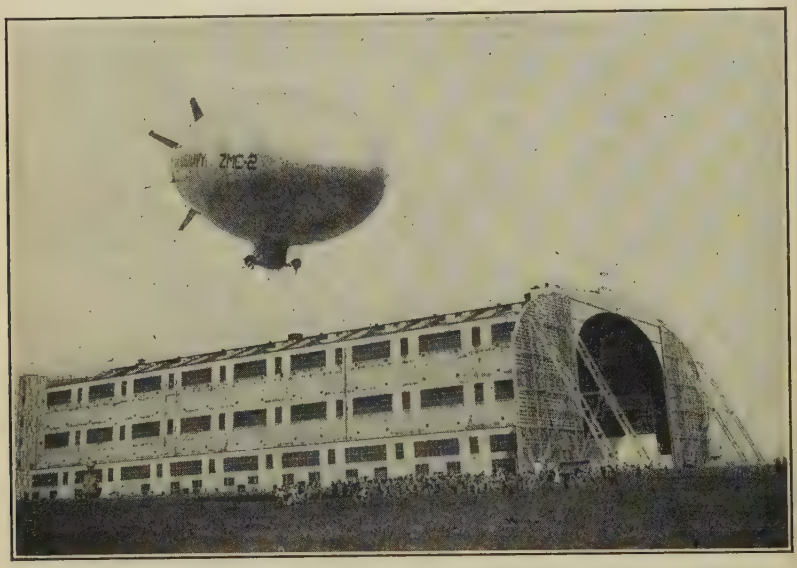
Dusting the boll weevil with calcium arsenate by means of an airplane.

fish, scribbles directions on a map, and places the map in a watertight carton which he drops in the water near the waiting fishing boat.

Surveying and map-making must also be added to the important services of the airplane. Besides, there is the remarkable service of the United States government mail planes, which carry important mail across the continent. The United

States Air Mail has made this country but one-third its former width, so far as communication is concerned.

Besides their use in long distance traveling, airplanes bid fair to become as common as automobiles for short trips. Newly perfected catapults for launching airplanes from small areas, and similar landing devices for bringing them to a quick halt, now make it possible to launch airplanes from



THE FIRST ALL-METAL DIRIGIBLE

The U. S. Army ship, ZMC-2. Thin sheets of Alclad, an aluminum alloy coated with pure aluminum, are used instead of silk as an envelope covering.

dirigibles, from ocean-going vessels, and even from submarines. These same devices would make it possible to launch and land a small plane from the roof of an office building.

ALUMINUM AND ZEPPELINS

Aluminum has had much to do with making airplanes light in weight and hence adaptable for the many uses to which they can be put. This same metal has likewise had quite a part to play in the development of airships. The metal framework

of the modern rigid Zeppelin is made of an aluminum alloy. In the painting of the canvas covering of Zeppelins, aluminum also has a part to play. The silvery luster of the *Shenandoah* was produced by a paint such as that used in silvering radiators and picture frames. This paint is made by mixing powdered aluminum with a suitable carrier. The use of an aluminum paint on the outside of the envelope is not for ornamental purposes, but it has been found that it reflects the rays of light from the sun and keeps the bags of gas inside from becoming warm and expanding rapidly.

Although the part that aluminum now has to play in the making of an airship is quite great, there is no doubt that the airships of the future will employ it even more widely. Metal coverings made of an aluminum alloy are taking the place of the present fabric coverings on Zeppelins.

USES OF ALUMINUM IN OTHER FIELDS

Aircraft are not the only vehicles that make use of aluminum, the lightest of the common metals. Many automobiles have solid aluminum bodies. Aluminum alloys are used for making the pistons of some automobile engines. Aluminum is now used in railway cars wherever possible because its light weight cuts down hauling costs. The Illinois Central suburban coaches were the pioneers in the use of aluminum and its alloys.

Aluminum has found many adaptations besides the making of agencies of transportation. One of the first uses to which it was put in this country was to cap the Washington Monument. Because of its light weight and wearing qualities, this metal was also used to cover the tower of the City Hall of Philadelphia.

The building of long-distance electrical transmission lines is another important use of aluminum. Although a wire of aluminum is larger in size than one of copper carrying the same current, its weight is smaller. It therefore puts less strain

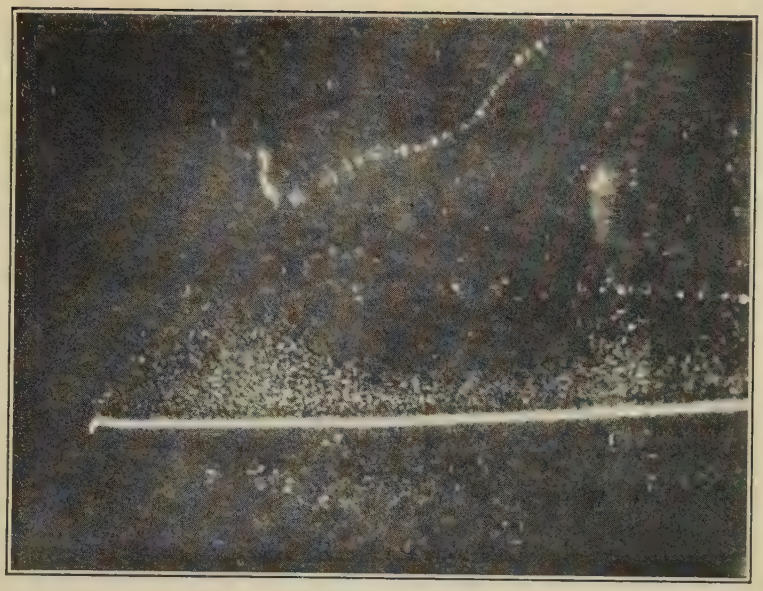
on the supports. The Northwestern Elevated Railroad of Chicago uses twenty miles of aluminum cables to transmit motive power to its cars. As aluminum becomes even cheaper than it is now, it will be used more and more extensively for this purpose.

Aluminum has come to be used quite extensively in the steel industry. Added to the molten iron instead of manganese, it removes blow holes quite satisfactorily, and is cheaper. In welding, a mixture of powdered aluminum and iron rust serves to mend large pieces without the necessity of taking them to the repair shop.

Aluminum powder burns with high heat and forms aluminum oxide. If mixed with iron rust, it takes its oxygen from the rust instead of from the air. This leaves metallic iron free and uncombined. During the burning of the aluminum, the iron melts under the intense heat and runs down through a funnel into the crevice to be mended. This process of welding is called the thermite process and was invented by Hans Goldschmidt, a German scientist.

Not least among the important uses of aluminum is in the making of kitchen utensils. This was one of the first practical uses to be made of aluminum, and is still one of the most important. Housewives nowadays equip their kitchens with kettles, percolators, buckets, measuring cups, salt and pepper shakers, tea strainers, dish pans, skillets, stew pans, dippers, and colanders of aluminum, the metal that was so rare half a century ago that only a baby rattle for a royal baby, and jewelry to sell for high prices, could be made of it.

The prediction has been made, and not without foundation, that aluminum will one day largely replace iron. This prognostication is based on the fact that aluminum is the most plentiful metal there is. Every clay bed is a veritable mine of this metal. The discovery of a cheap method of extracting aluminum from clay, the ambition that Hall had when he started his research, is only a matter of time.



A MINIATURE MILKY WAY

CHAPTER XX

AN EXTRAORDINARY METAL

Truth is stranger than fiction.

—Old Proverb

NO doubt the first copper needles of the time of King Snefru of ancient Egypt created quite a stir. But it is unusual in this day and age to expect a needle to arouse much excitement. The loss of a needle containing a very small amount of radium bromide, however, engaged the interest a few years ago of a great city and of many surrounding towns for several days. Here is the account, from the Kansas City *Star-Times,* of the search for this valuable article:

PHYSICIAN LOSES $1,500 NEEDLE

The proverbial hunt for a needle in a haystack would be easy compared to the task of finding a $1,500 needle in a city, which

confronts Dr. Clyde O. Donaldson. The needle is about an inch long and presents the appearance of the ordinary steel variety. Its excessive value lies in that its hollow interior is filled with radium.

Dr. Donaldson used the instrument in giving a radium treatment Tuesday afternoon. Shortly afterward he missed the precious needle. A thorough search of the office and laboratory failed to reveal its whereabouts.

Under the presumption that it had caught on the patient's clothing, Dr. Donaldson went to the patient's house in the Westport district and searched him, also making a visual search of the house. It was unsuccessful.

The physician has sent for an electroscope, an instrument used in detecting the presence of radium, with which he intends to search the route covered by the patient between Lathrop Building and his home. He will also search street cars the man may have ridden on the way home.

The apparatus will arrive by to-morrow. There are no portable electroscopes in Kansas City.

The day after the appearance of the first item, the following told of the continuance of the search:

THE NEEDLE STILL HIDES OUT

With the aid of a scientist and one of the most delicate instruments ever devised by scientists, Dr. Clyde O. Donaldson searched long and tediously to-day for a lost radium needle—and never came within five feet of it.

Dr. Donaldson has the dissatisfaction of knowing how "cold" he was because the sensitized aluminum indicator of the instrument, an electroscope from the University of Kansas, would have registered excitement if it had come within the five-foot zone. Dr. F. E. Kester of the physics department of the university brought the electroscope here and conducted the search. The needle is of steel and looks like an ordinary sewing needle, but it contains $1,500 of radium.

The electroscope paged Dr. Donaldson's office, where the loss of the needle was discovered Tuesday after a patient had returned a rubber pack in which he had been wearing it with three other needles. No luck—but there were other needles in use in the office

at the time, and that may have confused the electroscope. There will be another search of the office.

The hunt shifted to the home of the patient in the Westport district, and it was so thorough even a trash pile in which sweepings from the house were thrown was given an electroscopic third degree and found innocent.

For the men of the street the big thrill of the scientific treasure hunt will come this afternoon when the electroscope will be carried over every foot of the route the patient took when he went to his home from the office. Even the street cars he may have ridden will be put to the test—most everything might happen to a small needle alone in a big city.

James D. Reeves, representing the Aetna Casualty and Surety Company, gave a cheering word to-day that a radium needle lost in Des Moines was found with an electroscope from the University of Iowa. And then Dr. Donaldson clings to the thought that radium has no value in the open market and that it could be sold only to the government, radium manufacturers, or some one enough educated in science to use it.

The same afternoon that the above article appeared in the paper, the valuable radium-containing needle was found. In going over the exact route that the patient had taken on his way home from the doctor's office, even the same street car on which he had ridden was examined. Although it gave no trace of the needle, the electroscope showed excitement when the searchers alighted from the car where the patient had gotten off. And there it was found, nestling up near the curbstone, where it might have remained undetected indefinitely except for the delicate electrical instrument used in searching for it.

THE DISCOVERY OF RADIUM

Radium has been known for only a few years. The story of its discovery is one of the most interesting chapters in the history of man's search for materials. In the early nineties, Marie Sklodowska, a Polish girl who had been educated at the University of Warsaw, came to Paris to study for a higher

degree in science. She was possessed of such a small amount of money that it was necessary for her to live in a very poor room and to work as a laboratory assistant to support herself. Although she came of a well-known family of Polish educators, her people were far from well-to-do.

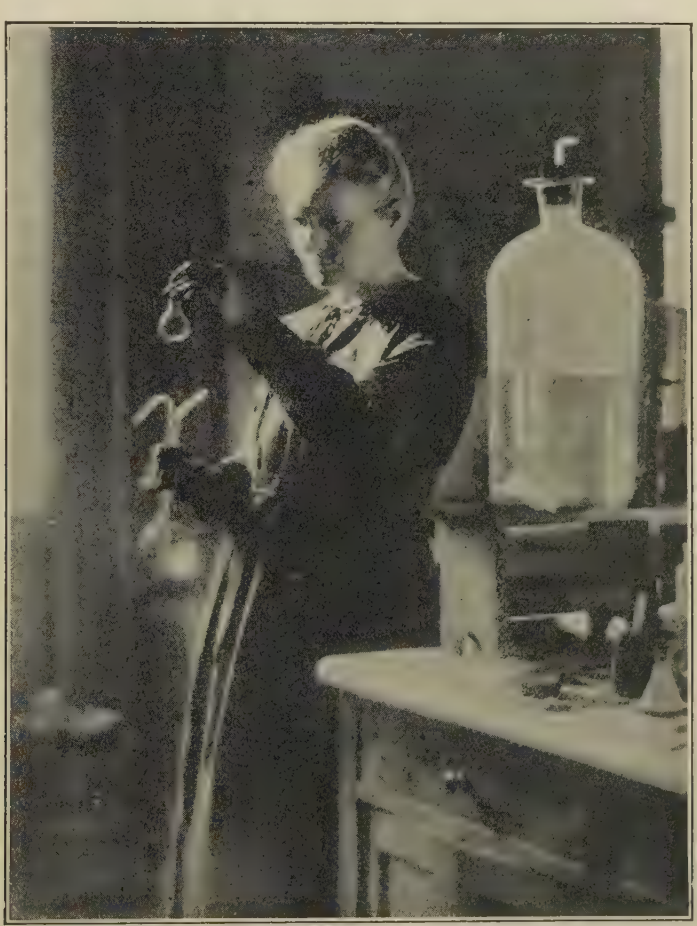
After Mlle. Sklodowska had studied for a time at the University of Paris, she was permitted by the professors there to undertake a piece of original research which should lead to the achievement of the degree of Doctor of Philosophy. She was assigned her research problem by Professor Henri Becquerel, who had been finding that his photographic plates were being ruined by exposure even when they were tightly wrapped and kept in a dark place. Upon investigation, Professor Becquerel found that some compounds of uranium upon which he was working were causing the trouble. Further study showed that uranium compounds gave off rays of light which could be seen in a dark room, and that they affected an electroscope in the same way as a body charged with electricity. No other substance previously discovered had been known to act in this way, and Professor Becquerel was truly at a loss to know how to account for the phenomenon.

When professors find questions of this sort which require investigation, it is frequently their custom to turn the matter over to one of their advanced students. This arrangement proves satisfactory, since the student can thus gain valuable experience, and the professor can direct a number of investigations at the same time. Although Professor Becquerel had a number of students working under him, he chose Marie Sklodowska for the uranium research because she had shown such remarkable ability in her previous studies.

In 1895, at about the same time that Marie Sklodowska began the researches leading to her degree, she was married to Professor Pierre Curie of the Physics Department of the University of Paris. In her wonderful book entitled *Pierre Curie*, Madame Curie describes the happy incidents surrounding the

work which she and her husband thereupon carried on together.

Meanwhile Madame Curie's researches took her far afield from the work that was originally planned. After obtaining



Photograph by Underwood and Underwood

MADAME CURIE IN HER LABORATORY

some of the ore called pitchblende, from which Professor Becquerel's uranium salts had been extracted, it was found that the residue remaining after the uranium had been removed by

chemical means had a much greater effect on the electroscope than the uranium itself. This was capable of but one interpretation, namely, that some hitherto unknown element was present in pitchblende. Madame Curie's research problem thereupon resolved itself into a search for this new element.

The pitchblende ore from which the uranium in question had been removed was obtained from Bohemia, the Bohemians having used uranium in the production of yellow glass, one of the fine colored glasses for which they are noted. Literally tons of pitchblende and pitchblende refuse were shipped from Bohemia to Madame Curie in Paris during the course of her search for the peculiar new substance which she believed to be hidden therein. When the laboratory at the university proved too small for the immense amount of ore which she was obliged to use, she rented a shack with considerable floor space not far from the apartment in which she and her husband lived, and moved her equipment into this. Here she worked all day long while Professor Curie was attending to his duties at the university. In the evening, after supper, the two of them would walk over to the shack together and go over the work of the day. The place was heated only by an old cook stove in one end, and, in her biography of her husband, Madame Curie tells of warming themselves with a cup of tea while they examined the contents of the huge laboratory dishes in which the solutions with which she was working phosphoresced in the evening twilight.

In 1903 Madame Curie received her Ph.D. degree. The thesis that she presented to the faculty of the College of Science of the University of Paris was a marvel of brevity and modesty, since it was in this paper that she announced to the world the discovery of a new element which she called *radium*, and which was entirely unlike any other element which had been previously discovered. At the time of the publication of this dissertation, Madame Curie had prepared but a small fraction of a gram of radium chloride, a compound of radium.

It was half a dozen years later before she succeeded in producing an amount of radium chloride great enough to permit of the isolation of metallic radium.

Meanwhile, in 1906, Professor Curie was accidentally killed by a dray as he was going home from a science meeting. His passing was a distinct loss to the scientific world. Shortly after his death, Madame Curie was appointed to fill his position as Professor of Physics at the University of Paris—the first woman to hold a position of this sort in Europe. Although she had two small daughters, she went to the task with her usual vigor, and kept her home going as well.

AN INTERVIEW WITH PIERRE CURIE IN 1903

"Worth three thousand times its weight of pure gold," said M. Pierre Curie in 1903, in an interview about radium with Cleveland Moffett, an American writer. This interview was published in the November issue of *Review of Reviews*. During the conversation, M. Curie disclosed many interesting facts about the metal which his wife, with his help and counsel, had so recently discovered: its scarcity; its lighting power (a kilogram lighting a room 30 feet square with a mild radiance); its warmth (a given quantity giving off enough heat to melt its own weight every hour); the testing of diamonds by its glow; and the inexplicable explosions that took place during experiments.

M. Curie explained that the mere presence of this element could annihilate animal and plant life:

> Here is one instance. On May 13, 1903, a little chloride of radium (about one five-hundreth of an ounce) was suspended over the cage of eight white mice, two parent mice and six little ones, and was left there three days and then removed. The mice continued to eat and run about as usual until May 16, when the little ones began to lose the fur on their backs. On the 19th, their backs were quite bare of fur, although their heads remained covered, which gave them the appearance of little white lions. On the 21st the

little ones became blind, although they continued to eat well. On the 23rd one of the little ones died. On June 5th both the parent mice became blind. On the 28th both the parent mice died. This was the work of the three grains of radium in a tiny glass tube.

In another case, two full-grown mice were exposed continuously to the same quantity (five centigrams) of radium for ten days. For nine days they remained perfectly well, although they showed some fear, but on the tenth day they died without losing their fur. This experiment was repeated with another pair of mice under the same conditions, except that the radium used was only half as intense, and in this case the mice died in twenty-two and twenty-six days respectively, they having begun to lose their fur on the twentieth day. . . .

Similar experiments were made upon other animals under varying conditions, the result being almost invariably death after a longer or a shorter time, according to the animal's resistance. . . .

Moffett related many other interesting things that he learned about radium from M. Curie: that radium changes the color of phosphorus from yellow to red; that radium rays increase the production of ozone in some cases; that a small quantity of radium salt dissolved in water throws off hydrogen constantly by causing a disintegration of the water, the oxygen released being absorbed in some unknown molecular combination; that a solution of radium gives a violet or brownish tint to a glass vessel containing it, this tint being permanent unless the glass be heated red-hot. In conclusion, Moffett wrote of M. Curie's experiments on diamonds with radium:

It was further established that radium offers a ready means of distinguishing real from imitation diamonds, since it causes the real stones to burst into a brilliant phosphorescence when brought near them in a darkened room, while it has scarcely any effect upon false stones. M. Curie made this experiment, a short time previously, at a reception in Lille, to the great delight of the guests.

RADIUM AND CANCER

During the War, Madame Curie drove a truck in which was kept some of the precious radium which her own laboratory

had separated from its ores after her remarkable discovery. The purpose of this radium was to treat wounds which might become cancerous if not looked after properly.

Soon after the discovery of radium, it was found to be a valuable substance in cancer treatment. The occasion of the discovery was when Professor Henri Becquerel traveled to London with a tiny glass tube of radium in his vest pocket in order to give a lecture on this remarkable new substance. About two weeks after his return he developed a deep burn on his flesh directly underneath this pocket. Subsequent investigations showed that radium was the cause of the burn. Still further experimentation showed that careful use of the substance would check the growth of cancer.

RADIUM IN AMERICA

Shortly after the discovery that radium was the best known material for treating cancer, the Bohemian government placed a strict embargo on pitchblende ore. This made radium particularly hard to get, especially in America. Consequently, Joseph M. Flannery, a Pittsburgh steel manufacturer, began to investigate the possibilities of producing radium in this country.

"In May, 1911," writes Dr. Charles H. Viol in *Radium*, "Joseph M. Flannery of Pittsburgh founded the Standard Chemical Company, and undertook to produce in the United States, from carnotite, a Colorado uranium ore, radium, that precious substance which until then had only been produced on a small scale in Europe."

Mr. Flannery was not only a man of vision [Dr. Viol continued], but also given to carrying through his plans, and so after two years of the hardest toil, the first radium to be produced on a commercial scale in the United States was refined in the Radium Research Laboratory of the Standard Chemical Company of Pittsburgh. This pioneer achievement of Mr. Flannery meant more than the building

up of a technical staff to duplicate the refining operations as practiced in the radium refineries of Europe, for the Colorado carnotite ore presented many new problems which had to be met and solved. Unlike pitchblende, carnotite ore occurs rather plentifully, but in the form of a very low grade sandstone ore, the carnotite material forming part of the cementing substance between the sand grains. The first problem which Mr. Flannery solved was that of concentrating this low grade ore so as to make a concentrate that could be transported more readily from the mines over the many miles of poor roads to the nearest railway, and so as to make the production of radium possible by the use of a reasonable tonnage of chemicals necessary for its extraction. Then came the radium itself and later the other values in the ore, vanadium and uranium, and at the time of his death, in February, 1920, Mr. Flannery had seen success assured to his efforts.

The production record of the Standard Chemical Company has been a remarkable one, over half of the world's stock of refined radium having come through the work in its mines, mills and laboratories. Since the discovery of radium in 1898 by Professor and Madame Curie in Paris, it is estimated conservatively that the world's total radium output has not exceeded 140 grams of radium element, and figures based on reasonable assumption makes the total not more than 120 grams. Of this total, approximately 100 grams have been refined in the United States, and 74 grams of this total represent the output of the Standard Chemical Company to June, 1921.

While visiting in Paris, Mrs. William Brown Meloney of New York, editor of the *Delineator,* made the acquaintance of Mme. Curie, and conceived the idea of having Mme. Curie visit the United States. Her pressing invitation was finally accepted, and on Mrs. Meloney's return to the United States, she founded the Marie Curie Radium Fund Committee with the purpose of having this committee secure by popular subscription from the women of the United States a fund sufficient to purchase a gram of radium which could be presented to Mme. Curie when she came on her visit to this country.

The committee was successful in its work, and when Mrs. Meloney sailed for France early in May to escort Mme. Curie to this country, she knew that her splendid idea had worked out successfully, and that the distinguished co-discoverer of radium would soon be the possessor of an adequate amount of radium of her own to carry

on researches, which had been held up by the lack of this precious material.

When asked what she would particularly like to see while in the United States, Mme. Curie expressed a desire to visit Pittsburgh, so that she might see the radium refining operations as conducted there on the largest scale by the refining Chemical Company, and to visit the Grand Canyon of the Colorado.

As was to be expected, it was the Standard Chemical Company of Pittsburgh that supplied the gram of radium which the women of America presented to Mme. Curie, and this has been written to give a better idea of what a gram of radium means, for many cannot conceive that a tiny pinch of material, a twenty-eighth of an ounce, can have an intrinsic value of $100,000.

Carnotite ore occurs in an area of many hundreds of square miles throughout the southwestern corner of Colorado and in southwestern Utah. It is found in larger or smaller pockets or seams, in a particular geological horizon, and as this level is not far from the surface of the plateau-like country, the earlier prospectors worked by observing the bright sulphur yellow carnotite débris which occurred on the canyon or valley sides; and by following this back, located the pocket or seam near the "rim rocks" which gave rise to the débris. Systematic drilling with a diamond core drill, as carried out by the Standard Chemical Company on the flats back from the canyon and valley walls, has brought to light much ore that would otherwise not have been found, and a conservative estimate of the radium recoverable from the properties of the Standard Chemical Company places the figure at upwards of a thousand grams.

The carnotite seams are narrow, and so the securing of milling ore involves taking out a great deal of worthless rock, one ton of average milling ore requiring the mining of about five tons of rock and ore. From this mined material, the milling ore is taken by hand sorting, the sorted ore being sacked and hauled down the hillside trails to the roads by burro. Picked up by truck or wagons, the milling ore is hauled ten to forty miles to the concentration mill of the Standard Chemical Company located on the San Miguel River, about sixty-five miles from Placerville, Colorado. To secure one gram of radium in the finished product, an average of 500 tons of the milling ore must be used.

When received at Canonsburg, Pennsylvania, twenty miles southwest of Pittsburgh, the carnotite is carefully washed and then treated

drastically with chemicals to remove all possible barium and radium salt. The ore concentrate contains about ten parts per billion of radium and about one-half per cent of barium salt. The chemical similarity of the barium and radium permits the extraction of the radium by the removal of the greater quantity of barium salt. The solution of radium and barium is treated with sulphates to precipitate an insoluble "raw sulphate" of radium, one gram of radium being contained in about a ton of such crude sulphate. This sul-

Courtesy Radium Luminous Material Corp.

THREE MILLION DOLLARS' WORTH OF RADIUM

Showing the finishing stages of extraction of the substance from carnotite ore.

phate is carefully purified and treated to yield nearly pure barium-radium chloride, about 1,000 pounds of this material containing the gram of radium. To secure this quantity of radium-barium chloride requires the chemical treatment of carnotite concentrate from 500 tons of milling ore and the use of 500 tons of various chemicals, acids, and alkalies, the power from 1,000 tons of coal, the use of upwards of 10,000 tons of purified and distilled water, and the labor of 150 men for a month.

The further refinishing of the radium-barium chloride is essentially a process of fractional crystallization, as first devised by Mme. Curie, since no single chemical operation is capable of removing the tiny quantity of radium from the huge amount of accompanying barium salt. The purified radium-barium chloride, after a preliminary crystallization on a large scale at Canonsburg, is then shipped to the Radium Research Laboratory of the Standard Chemical Company of Pittsburgh, and here the final delicate operations of fractional crystallization, first as chloride and then as bromide, are performed, the final product obtained after five weeks' operations being a tiny pinch of nearly pure radium bromide, which, when freshly evaporated from solution, exactly resembles powdered sugar. On standing in a sealed tube, the salt acquires a brownish color and loses some of the bluish phosphorescent glow which at first is quite marked when the salt is observed in the dark.

For most medical uses the insoluble sulphate of radium is usually supplied, the salt being hermetically sealed in suitable small glass tubes, in metal needles, or fused in the surface of a glaze on a metal plaque. The medical use of radium consists in the exposure of the diseased parts to a suitable amount of radium, whose radiations, like the x-rays, penetrate and influence the diseased tissues. Used in this way, the radium is not exhausted, and its natural decay, inherent to radioactive substances, is such that only in 25 years is one per cent of its substance transmuted, and at this rate it requires 1,700 years for the decay of half of any quantity of radium.

Six months are consumed in the production of radium, from the mining of the ore to the tubing of the finished salt, and after this the material must "age" or mature for thirty days to attain its maximum activity, when it is shipped to the United States Bureau of Standards at Washington, D. C., to have its activity certified.

To produce a gram of radium per month requires the work of 200 miners and mill men in Colorado, 150 men in the Chemical Works at Canonsburg, and 15 technical men in the Radium Research Laboratory at Pittsburgh, without making allowance for the auditing, sales, and executive departments; the mining and milling of 500 tons of ore, and the chemical treatment of ore concentrate, involving the use of 500 tons of chemicals, 1,000 tons of coal, 10,000 tons of water, and work extending over six months. Truly a vast labor and expense to yield half a thimbleful of radium salt; and at such a cost of production, radium sells cheaply at the price of $100,000 per gram. [This was in 1921.]

Such is the story of the production of the gram of radium which was presented by President Harding, on behalf of the women of the United States of America, to Mme. Curie, at the White House, on the afternoon of May 20, 1921, in the presence of a distinguished assemblage of over five hundred who represented women's organizations, the cabinet, the diplomatic corps, congress, and distinguished leaders in medical, chemical, physical, and other scientific fields.

NEW FINDS OF RADIUM

Just previous to 1921, radium was selling at $125,000 per gram. The gram of radium that was presented to Madame Curie in 1921 cost $100,000. Late in that year, radium-bearing ores were discovered in the Upper Katanga (Belgian Congo), and a plant for concentrating the ores was hastily established. The ores were shipped from the Belgian Congo to Belgium for final treatment. This decidedly increased the quantity of radium on the market and brought down the price considerably.

When, in 1929, Madame Curie made a second trip to the United States, this time to receive a gift of a second gram of radium, the market price was listed at $70,000 a gram. The price has been reduced considerably since that time. A continuance of this drop will take place, provided methods of extraction are shortened and new supplies of the ore continue to become available.

It is interesting to note that Madame Curie refused to accept the gifts of radium presented to her in this country as her own personal property, but gave the first gift to the University of Paris and the second to her own Polish school, the University of Warsaw.

RADIUM-DIALS

On an ordinary radium-dial on a watch there is about 20 cents' worth of radium. This presents an interesting problem in arithmetic. Although at the present time the price of radium

has fallen materially because of discoveries of valuable ores in the Belgian Congo, the amount that one could purchase for 20 cents could sit very comfortably on the peak of the proverbial needle and leave most of the room vacant.

The phosphorescent substance on a watch dial is zinc sulphide or some similar compound. This substance has been found to become phosphorescent if activated by an unbelievably small amount of radium. It may likewise be activated by a few bodies not usually considered as radio-active, but the phosphorescence is of shorter duration.

The use of radium to make bodies luminous was developed largely during the late war. It was found to be a decided advantage to be able to illuminate controls on airplanes and submarines and sights on guns and switchboards, without a telltale light. Bodies thus illuminated are not visible even at a few yards, but at several feet show up very distinctly. Other uses of luminous bodies which have been developed are: luminous markers for poison bottles, luminous faces on clocks and watches; luminous radio dials; and luminous automobile controls.

JOHN DALTON AND THE VILLAGE CHILDREN COLLECTING MARSH GAS

CHAPTER XXI

THE STRUCTURE OF STUFF

Everything in Nature contains all the powers of Nature. Everything is made of one hidden stuff.

—EMERSON

THE DISCONTINUITY OF MATTER

THE behavior of substances cannot be satisfactorily explained unless we assume that matter is discontinuous —that is, that it consists of units of structure which are separated from each other by spaces. The following description by Bertrand Russell explains this point:

To the eye or to the touch, ordinary matter appears to be continuous; our dinner tables, or the chairs on which we sit, seem to present an unbroken surface. We think that if there were too many holes the chairs would not be safe to sit on. Science, however, compels us to accept a quite different conception of what we are pleased to call "solid" matter; it is, in fact, something much more like the Irishman's net, "a number of holes tied together with pieces of string." Only it would be necessary to imagine the strings cut away until only the knots were left.

HISTORY OF THE ATOM

Although John Dalton is often called the "father of the atomic theory," the idea of atoms is of ancient origin. In the writings of the ancient Chinese and Hindu philosophers, the belief in the discontinuity of matter and the existence of ultimate indivisible particles is common. At a much later period, the ancient Greek philosophers speculated upon the structure of matter, and most of them appear to have been believers in the atomic theory. Leucippus, a Greek philosopher living about 500 B.C., is regarded as the founder of the Greek Atomistic philosophy. According to him, all things consisted of

atoms (the word *atom* comes from the Greek word meaning "uncuttable") and empty spaces. He believed that atoms were infinite in number, and that spaces were infinite in size. He believed that the atoms were in constant motion.

The theories of Leucippus were taken up by Democritus, who had been his pupil. Democritus defended his atomistic views thus: "If every substance is divisible to infinity, and the division is never arrested, we come to one of two things: either nothing remains or something always is left." From this he concluded: "It is necessary to admit the existence of real indivisible elements."

There is to be found in the writings of Leucippus and Democritus an expression of the belief in some primal homogeneous matter. Later Greek thinkers argued this point and the whole theory of atomic structure, until two distinct schools of thought were founded. The Peripatetics, under the leadership of Aristotle, considered matter as continuous and filling all space. The Atomists, on the other hand, led by Epicurus and other followers of Leucippus and Democritus, maintained that matter does not fill all space, but that it is built up of ultimate particles which cannot be further divided.

It was not possible for the Greek thinkers to arrive at any direct decision concerning the structure of matter, since all direct proof was lacking. They had to resort to debate and logic, and the loudest talker and the cleverest writer won the argument.

For about sixteen or seventeen centuries following this period of Greek culture, people lost interest in atoms altogether, and took up what seemed to be a more profitable undertaking—the transmutation of elements. The whole idea, of course, was the hope of producing precious metals from cheaper ones, not by philosophic speculation, but by trying out everything, hit-or-miss fashion, in the laboratory.

It was not until the eighteenth century that Boyle, Priestley, Scheele, and others began experimenting merely for the sake

of gaining knowledge. With the introduction by Lavoisier of the quantitative balances into laboratory study, it was no longer necessary to resort to debate as the only means of deciding how substances are constituted.

John Dalton made his wonderful contributions to the knowledge of the structure of matter by studying chemical reactions quantitatively, and deriving an atomic theory that was based on experiment rather than upon argument.

DALTON'S CONTRIBUTION

These are the ideas introduced into the atomic theory by Dalton:

(1) The ultimate particles of a pure substance, whether simple or compound, are all exactly alike.

(2) The atoms of elements are indivisible [this point has, of course, been found to be in error].

(3) The molecules of substances, elementary or compound, are formed by the union of two or more elementary atoms.

(4) Combinations between atoms take place in the simple integral ratios.

JOHN DALTON'S AUTOBIOGRAPHY

The following brief account of Dalton's life was written by the scientist himself:

The writer of this was born at Eaglesfield, about two miles west of Cockermouth, Cumberland [England], September 5, 1766. Attended the village schools there and in the neighborhood till eleven years of age, at which period he had gone through a course of mensuration, surveying, navigation, etc.; began about twelve to teach the village school, and continued it two years; afterwards was occasionally employed in husbandry for a year or more; removed to Kendal at fifteen years of age as assistant in a boarding-school; remained in that capacity for three or four years, then undertook the same school as principal, and continued it for eight years; whilst at Kendal, employed his leisure in studying Latin, Greek, French, and

the mathematics and natural philosophy in the New College; was six years in that engagement, and after was employed as private and public teacher of mathematics and chemistry in Manchester, but occasionally by invitation in London, Edinburgh, Glasgow, Birmingham, and Leeds.

JOHN DALTON

Oct. 22, 1832

A TWELVE-YEAR-OLD TEACHER

At the age of twelve, John Dalton posted a large sheet of white paper on his father's door (his father was a weaver by trade), on which he announced that he would open a school on reasonable terms for both sexes. Some time later this sign was accompanied by a second which said that "paper, pens, and ink" were sold within.

At first, Dalton taught his school in an old barn. Later he removed to his father's house, and finally to the Friends' Meeting House of Eaglesfield, his native village. His scholars were of all ages, from infancy to seventeen years. The younger ones received personal instruction in the mysteries of A, B, and C while John held them on his knee. Some of the older pupils gave him considerable trouble by playing leapfrog over the tombstones in the meetinghouse cemetery. The exact degree of success which this youthful instructor achieved in his first pedagogical enterprise is not recorded by any of his biographers. At any rate, he must have been sufficiently successful to have attracted some notice, for he was chosen at the age of fifteen as an assistant in a boarding school.

Even while Dalton was carrying on atomic researches which were destined to revolutionize modern thinking, he continued his occupation of teaching children.

RECENT ADDITIONS TO DALTON'S THEORY

Although Dalton's atomic theory was good as far as it went, many recent additions have been made to it. He pictured

atoms as taking part in chemical reactions, and laid the foundations for all of our modern work with reactions. His atom, however, was a small, round, impenetrable particle without any internal anatomy. Scientists now have concrete proof that atoms have units of structure of quite a definite and complicated character.

In technical papers written in 1815 and 1816, a German chemist expressed the opinion that the primal substance that the ancients wrote about might be the element hydrogen. This view came to be called Prout's Hypothesis, and was much talked about at the time.

In view of modern experimental evidence, we now believe that all elements consist of two types of electrically charged particles, protons (positively charged particles) and electrons (negatively charged particles). To state the theory more definitely, we believe that all elements consist of a nucleus composed of a certain number of protons and electrons, around which other electrons are revolving in certain fixed orbits. All protons are alike, and all electrons are alike, regardless of the element in which they are found. In other words, nature employs two kinds of bricks in element-building—in this case, protons and electrons.

The mass of the element is centered in the proton. The electron has mass, but is too small to be measured in our everyday units. The atomic weight of an element therefore depends upon the number of protons in the nucleus. Other properties of the atom are dependent upon the number and arrangement of electrons in the atom.

ATOMIC NUMBERS

If the ninety-two elements be arranged in the order of their atomic weights, and each one assigned a number corresponding with its place in the list, this number is also equivalent to the number of electrons which the atom of this particular element

has outside of the nucleus. This number is called the atomic number of the element.

The following table gives the elements in order, with the electrons outside the nucleus grouped according to the number in each orbit:

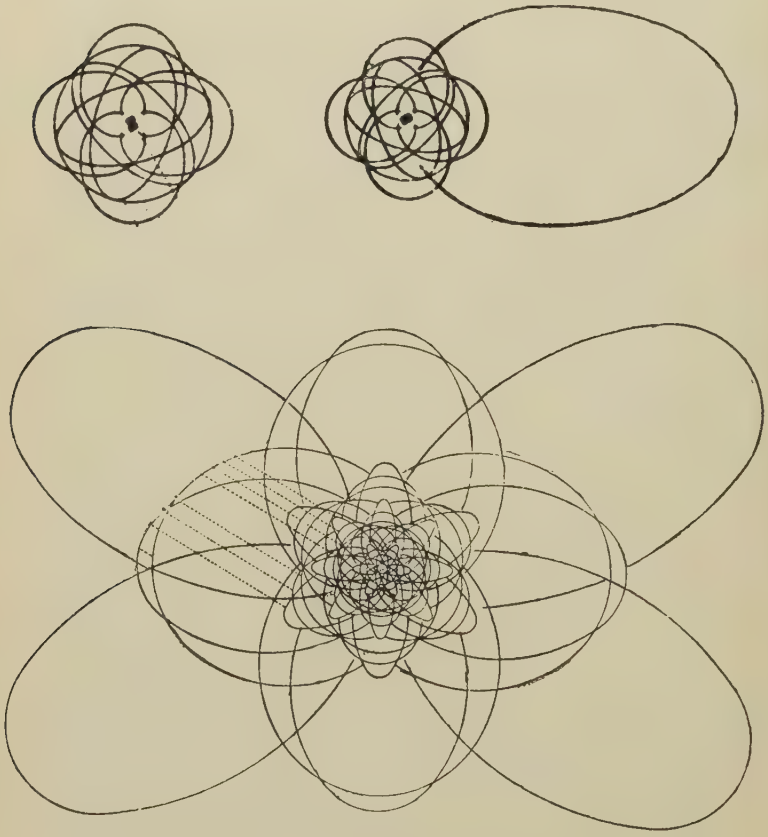
Atomic Number		*Electronic Orbits*				
1	Hydrogen	1				
2	Helium	2				
3	Lithium	2	1			
4	Beryllium	2	2			
5	Boron	2	3			
6	Carbon	2	4			
7	Nitrogen	2	5			
8	Oxygen	2	6			
9	Fluorine	2	7			
10	Neon	2	8			
11	Sodium	2	8	1		
12	Magnesium	2	8	2		
13	Aluminum	2	8	3		
14	Silicon	2	8	4		
15	Phosphorus	2	8	5		
16	Sulphur	2	8	6		
17	Chlorine	2	8	7		
18	Argon	2	8	8		
19	Potassium	2	8	8	1	
20	Calcium	2	8	8	2	
21	Scandium	2	8	9	2	
22	Titanium	2	8	10	2	
23	Vanadium	2	8	11	2	
24	Chromium	2	8	12	2	
25	Manganese	2	8	13	2	
26	Iron	2	8	14	2	
27	Cobalt	2	8	15	2	
28	Nickel	2	8	16	2	
29	Copper	2	8	18	1	
30	Zinc	2	8	18	2	
31	Gallium	2	8	18	3	
32	Germanium	2	8	18	4	
33	Arsenic	2	8	18	5	
34	Selenium	2	8	18	6	
35	Bromine	2	8	18	7	
36	Krypton	2	8	18	8	
37	Rubidium	2	8	18	8	1
38	Strontium	2	8	18	8	2
39	Yttrium	2	8	18	9	2
40	Zirconium	2	8	18	10	2
41	Columbium	2	8	18	11	2
42	Molybdenum	2	8	18	12	2
43	Undiscovered	2	8	18	13	2
44	Rubidium	2	8	18	14	2
45	Rhodium	2	8	18	15	2
46	Palladium	2	8	18	16	2

Atomic Number		*Electronic Orbits*					
47	Silver	2	8	18	18	1	
48	Cadmium	2	8	18	18	2	
49	Indium	2	8	18	18	3	
50	Tin	2	8	18	18	4	
51	Antimony	2	8	18	18	5	
52	Tellurium	2	8	18	18	6	
53	Iodine	2	8	18	18	7	
54	Xenon	2	8	18	18	8	
55	Cæsium	2	8	18	18	8	1
56	Barium	2	8	18	18	8	2
57	Lanthanum	2	8	18	18	9	2
58	Ce	2	8	18	19	9	2
59	Præsodymium	2	8	18	20	9	2
60	Neodymium	2	8	18	21	9	2
61	Illinium	2	8	18	22	9	2
62	Samarium	2	8	18	23	9	2
63	Europium	2	8	18	24	9	2
64	Gadolinium	2	8	18	25	9	2
65	Terbium	2	8	18	26	9	2
66	Dysprosium	2	8	18	27	9	2
67	Holmium	2	8	18	28	9	2
68	Erbium	2	8	18	29	9	2
69	Thulium	2	8	18	30	9	2
70	Ytterbium	2	8	18	31	9	2
71	Lutecium	2	8	18	32	9	2
72	Hafnium	2	8	18	32	10	2
73	Tantalum	2	8	18	32	11	2
74	Tungsten	2	8	18	32	12	2
75	Undiscovered	2	8	18	32	13	2
76	Osmium	2	8	18	32	14	2
77	Iridium	2	8	18	32	15	2
78	Platinum	2	8	18	32	16	2
79	Gold	2	8	18	32	18	1
80	Mercury	2	8	18	32	18	2
81	Thallium	2	8	18	32	18	3
82	Lead	2	8	18	32	18	4
83	Bismuth	2	8	18	32	18	5
84	Polonium	2	8	18	32	18	6
85	Undiscovered	2	8	18	32	18	7
86	Niton	2	8	18	32	18	8
87	Undiscovered	2	8	18	32	18	8	1
88	Radium	2	8	18	32	18	8	2
89	Actinium	2	8	18	32	18	9	2
90	Thorium	2	8	18	32	18	10	2
91	Uranium X	2	8	18	32	18	11	2
92	Uranium	2	8	18	32	18	12	2

THE STRUCTURE OF THE ATOM

The hydrogen atom is the lightest and simplest of the atoms. It consists of one proton, which serves as a nucleus, around which one electron revolves in a circular orbit.

The atom next in weight to hydrogen is helium. Helium is four times as heavy as hydrogen. The nucleus consists of four protons and two electrons. Two electrons revolve in circular



STRUCTURE OF REPRESENTATIVE ATOMS

orbits around the nucleus, the plane of the orbits being at an angle of 120 degrees to each other.

Lithium, the third one of the elements, has a structure similar to helium except that the nucleus has added three additional protons and two additional electrons. It has also added one

electron in an outer orbit. This third electron moves in an elliptical orbit, on one side of which it moves quite close to the nucleus. On the other side, it moves quite outside the regions of the first two electrons. This outer electron gives lithium its valence of one, because compounds are formed when elements share outer electrons with each other.

In the next element in atomic weight, the nucleus likewise increases in number of protons according to its atomic weight. It adds one additional electron in the outermost orbit. This rotates in an elliptical orbit symmetrical with the outer electron of lithium. It therefore also adds a sufficient number of electrons to the nucleus to make its total number of positive and negative charges equal.

Boron, the next element in weight, has three electrons in outer orbits. Carbon has four; nitrogen, five; oxygen, six; fluorine, seven; and neon, eight.

With neon, the atom reaches a high degree of stability, because the eight outer electrons possess a high degree of stability and seem incapable of sharing orbits with the outer orbits of other elements. Neon is therefore a chemically unreactive gas.

Lithium, a metal with one outer electron, and fluorine, a non-metal which lacks one of having eight electrons in its outer orbit, can combine to form a molecule with eight electrons in the outer shell. The valence of each of these elements is said to be one, and the compound that they form is quite as inert as neon.

Sodium begins a series of elements, the nucleus of whose atoms increases in number of protons and electrons, but whose first two electron orbits are identical with those of neon. It adds one electron, however, in a third orbit. Magnesium has two outer electrons; aluminum, three; silicon, four; phosphorus, five; sulphur, six; chlorine, seven; and argon, eight.

Potassium begins another series by adding one electron in a fourth orbit. The next element in the series—calcium—adds a second electron to this fourth orbit. The next eight elements

have these same two outer electrons and no more, but they add electrons, one by one, to the third orbit, until the number in this orbit reaches eighteen.

This peculiar development of one of the inner orbits recurs a number of times as we go down the list of the elements.

ORIGIN OF THE WORD ELECTRON

Thales of Miletus, about 600 B.C., first noticed that the rubbing of amber would induce a remarkable state now known as electrification. The word *electron* was the old Greek word for "amber." When any substance became invested with the same properties as rubbed amber, it was said to have been electrified or amberized.

Aside from the experiment of Thales of Miletus, there is no record of electrification until 1600 A.D., when Gilbert, Queen Elizabeth's surgeon, found that a glass rod and a large number of other bodies became electrified when rubbed with silk; and it is to this scientist and surgeon that the coinage of the word *electrified* is usually attributed.

In 1733, Dufray, a French physicist, further found that sealing wax, rubbed with cat's fur, was also electrified, but that it differed from the glass rod rubbed with silk in that it would attract any body that was repelled by the electrified glass. He was therefore led to the conclusion that there were two kinds of electricity, which he called "vitreous" and "resinous."

About 1747, Benjamin Franklin called the two kinds of electricity positive and negative. Thus, he said, we will arbitrarily call any body positively electrified if it is repelled by a glass rod rubbed with silk; and we will call it negative if it is repelled by sealing wax rubbed with cat's fur.

The modern view of electricity is that negative electricity consists of electrons, and that what we call an electric current is merely the movement or transfer of electrons through a wire.

When a glass rod is rubbed with silk, it is supposed that some of the electrons of the glass are rubbed off. Having lost electrons, therefore, the glass assumes a positive charge. Sealing wax rubbed with cat's fur, on the other hand, is assumed to have gained some electrons from the cat's fur and therefore to be negatively charged because of an excess of negatively charged particles.

POKING FUN AT THE ATOMS

When it was found that atoms, hitherto considered indivisible, had complicated internal structures, the humorists could not refrain from having a little innocent fun at their expense. Thus, H. C. of L., writing for the "Lion's Mouth" of *Harper's Magazine,* said:

. . . I have been reading—as who has not?—some books about the structure of the atom. Take one of the letters on this page. Divide it up into a billion pieces. Segregate one of them. Divide that up into a thousand pieces. Let us carry one of these pieces to the laboratory and study it. What shall we find? No one can tell exactly. But the descriptions of those who have looked in suggest something like a ballroom scene where a vast number of dancers dance at inconceivable speed to a vast number of tunes. . . .

But this description is irrelevant or at least flippant. Let us then borrow the favorite simile of popular science and compare the atom to a tiny solar system. . . . For if the atom is a small solar system, why may I not say that the solar system is just a large atom? . . . Thus I have at my command a neat *tu quoque,* for if the solar system hurls itself at my head, so to speak, as much as to say, "You miserable little atom, you!" I can reply "Atom yourself!"

THE QUANTUM THEORY

Physicists now believe not only that matter is made up of small unit particles, but also that energy is emitted in definite amounts, or bundles, as some scientists say. In other words, neither matter nor energy is continuous. This "atomic theory

of energy" is called the quantum theory. It was first proposed by the German physicist, Planck.

ISOTOPES

The thoughtful student has no doubt been perplexed because atomic weights are not always whole numbers. Particularly in view of the statement that the atomic weight of an element

THE PUZZLED PHYSICIST

The scientist writes some mystic mathematical formulas concerning the behavior of the inside of atoms. (Drawing by courtesy of Van Veltzer, Physics Department, Pennsylvania State College.)

depends upon the number of protons in the nucleus, the hydrogen nucleus consisting of one proton, the problem of uneven atomic weights seems perplexing. A brief discussion of isotopes will help to clear up this matter.

Let us open the discussion with lithium. The chemical atomic weight of this element, as found naturally, is 6.94. The reason for this is the fact that some lithium atoms have 6 protons and 3 electrons in the nucleus, and some have 7 protons and 4 electrons. All atoms of lithium have the same number and arrangement of electrons outside the nucleus. In naturally occurring lithium, these so-called isotopes are in such

a proportion as to give a mean value of 6.94 for the atomic weight as determined by the usual chemical methods.

Boron has two isotopes, with atomic weights 10 and 11 respectively. The number of atoms having an atomic weight of 11 outnumber those of 10, and the atomic weight is 10.9. Magnesium has three isotopes; zinc appears to have four; krypton has six; and xenon seems to have as high as nine.

There are many other isotopic elements besides those mentioned. In fact, it is quite definitely believed that the atomic weights of all atoms (except that of hydrogen) are, within experimental error, whole numbers. In other words, with the exception of hydrogen, a fractional atomic weight means that all atoms of the element in question do not have the same number of protons and electrons in the nucleus. All atoms of the same element are alike as to the electrons outside the nucleus.

But what about hydrogen? The case of this element is unique. Although its atom consists of a single proton as nucleus, with one planetary electron, the atom of helium is not quite four times as heavy, and that of oxygen is not quite sixteen times as heavy, as that of hydrogen.

A number of years ago atomic weights were not taken to the third and fourth decimal places, and this very slight discrepancy was not known. When later this was found out, it was decided to let the atomic weight of oxygen stand at 16 and change that of hydrogen to 1.008, since oxygen enters into direct union with more elements than does hydrogen. Moreover, to allow hydrogen to remain as exactly 1 would involve changing the weight of every element in the third decimal.

How is it that four atoms of hydrogen weigh slightly more than one atom of helium, when the latter contains four times as many protons as hydrogen? This is explained by scientists on the basis of the so-called "packing effect." Whereas physics and chemistry teachers were formerly accustomed to talking about matter and energy as if they were two distinct considerations, it has been found more recently that the two are insepa-

rable from each other. In other words, the mass of a material substance (which we measure as weight) is in some way dependent upon its energy content. When a number of protons are packed together in the nucleus of an atom, therefore, the mass is slightly less than the total mass of this same number of protons taken independently, because of a slight change in energy which accompanies the packing phenomenon.

RADIUM AGAIN

It has been definitely determined since the discovery of radium that the peculiar behavior of this metal is a property of its atomic nature. The heat and light energy given off during the disintegration of radium are produced by changes taking place within the atom.

Radium emits three kinds of rays. This fact was determined by causing the radiations to pass through electrical fields when it was found that they split into three streams. Two of these streams were capable of being deflected from their original paths, which showed that they were streams of material particles carrying electrical charges. The third stream was not affected by the electric field, showing that it consisted of energy waves only.

The rays emanating from radium have been classified as follows:

RADIUM RAYS

Alpha (α) or positive rays consist of particles identical with nuclei of helium atoms, i.e., they contain four protons and two electrons. Having an excess of protons, they are therefore positively charged. These undoubtedly come from the radium nucleus. These particles travel with a velocity of 20,000 kilometers a second, but they have poor penetrating qualities. In fact, they are brought to a standstill by traveling through only a few centimeters of air.

Beta (β) or negative rays consist of streams of electrons, traveling (???) per second. When a portion of the nucleus separates from the remainder of the atom of radium, two extra electrons are left in the outer orbits. These forthwith depart from the atom, constituting the so-called beta-rays of radium.

This differs from an ordinary chemical reaction in that it is independent of temperature or pressure, and of all other conditions. Every step of the process is a matter of experimental proof. The material remaining after the departure of alpha—and beta—particles is a new element called radon. or sometimes niton.

Radon is a gas that has been isolated and its properties studied. It may be liquefied at −65 degrees centigrade, and solidified at −70 degrees centigrade. It is chemically inert and falls into the same family in the Periodic Table as helium, argon, and the other inert gases. The helium nuclei, constituting the so-called alpha particles, have also been studied spectroscopically and in other ways. The escaping electrons have been found to have the same properties as cathode rays and other rays known to consist of electron streams.

The following statement concerning the radium atom, from *The Story of the Atom,* by Shearcroft, is interesting:

> Radioactivity in no way destroys the idea of an atom; it only gives it a wider meaning. No longer a structureless piece of matter, it has been shown capable of being split up into other and, presumably, simpler atoms. No fresh definition of the atom is necessary. The atom of radium is still an atom of radium so long as it exists as radium. Now we look upon it as possessing new properties, the power to disintegrate, after which it no longer exists as radium.

Gamma (γ) rays are not deflected by an electric field. They are, in fact, similar to X-rays in that they are mere electromagnetic disturbances. They differ from X-rays only in wave length.

The reaction that actually takes place when radium disintegrates is not a matter of mere conjecture. The products formed have actually been studied and their properties analyzed. The following statement, therefore, is one of fact and not of theory:

1 Atom Radium—	1 Helium Nucleus =	1 Atom Radon +	2 Electrons + Energy
At. Wt.— 226	4	222	
Nucleus—226 + 138 −	4 + 2 −	222 + 136 −	
Electrons— 88	0	86	
Outside Nucleus			

EXPERIMENTAL FACTS CONCERNING ATOMIC STRUCTURE

The physicist and mathematician have come to the aid of the chemist in computing data concerning the size, speed, number, and structure of the atoms of various elements. It is difficult for one who is not trained in the fine points of mathematical chemistry and physics to comprehend all of the experiments that have been performed along this line. But a few features concerned with the subatomic investigations are not difficult to understand.

When alpha particles are allowed to pass through other gases, the state of affairs is comparable to a billiard ball in flight. The only thing that causes an alpha particle to be deflected is a collision with another nucleus. By photographing its path through various gases (which can be done because of the condensation of moisture behind it), it can be calculated how many atoms it shoots through without being deflected from its original path. When it does make a break in its path, it is possible to measure the angles of incidence and deflection, and the diameter and mass of the nucleus being struck.

Staging a collision between locomotives used to be quite a movie stunt, but photographing the collision of particles about a million-millionth of an inch in diameter moving 10,000 miles a second is even more of a feat. Professor W. D. Harkins of the University of Chicago was one of the first persons to make photographs of this sort.

A study of the X-ray spectra of elements tells scientists a great deal about the inner rings of electrons in complex atoms. The optical spectrum, on the other hand, tells about the electrons in the outer ring.

As further proof of the present beliefs concerning atomic structure, Rutherford and Chadwick, of Cambridge University, England, have bombarded atoms of various elements with alpha rays (helium nuclei spontaneously expelled from radioactive substances) and have succeeded in expelling hydrogen nuclei from a number of elements, thereby effecting the transmutation of a number of elements.

The work of J. J. Thompson, an English scientist, with so-called positive rays is also important in a study of experimental facts relating to atomic structure. He has shown that, in a cathode tube, we have not only streams of electrons from the cathode, but streams of positively charged particles toward it. By making a hole in the cathode, these positive, or as they are sometimes called, canal rays, can thus be studied independently of the cathode rays.

Thompson constructed an apparatus in which he subjected positive rays to an electromagnetic field and photographed the paths they took. Since the positive rays consist of nuclei of the elements under investigation, he was able to determine their mass from their angles of deflection. These corresponded very closely to the atomic weights found in the regular way.

THE COOLIDGE TUBE

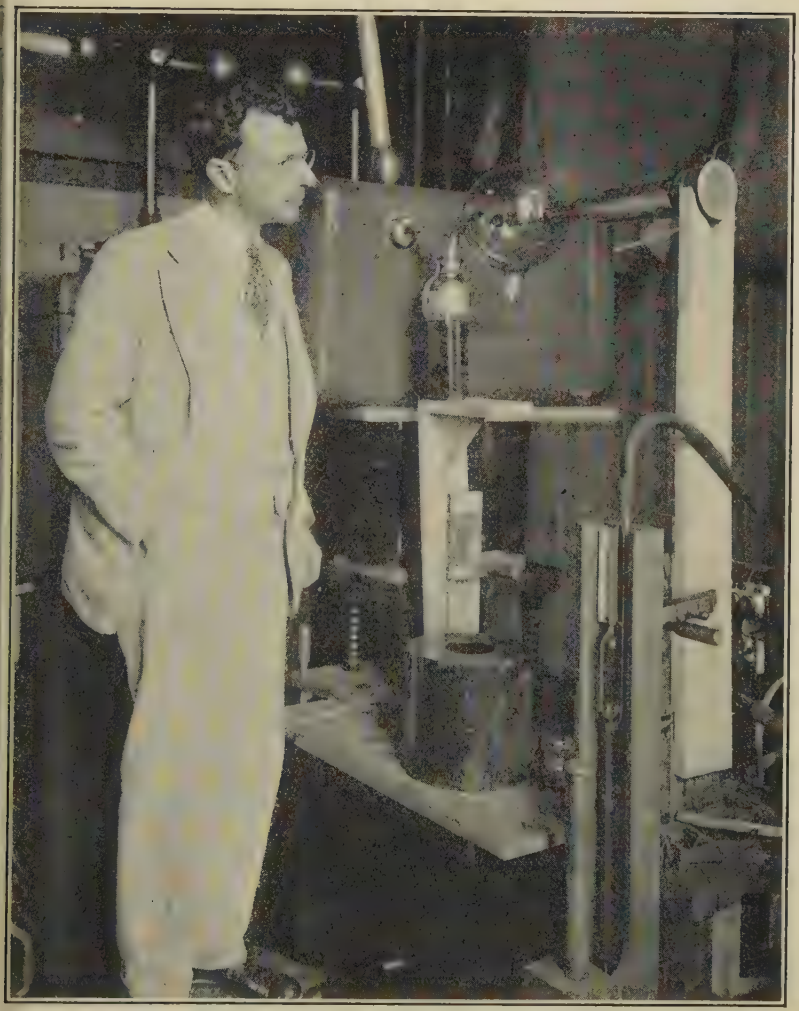
Dr. William D. Coolidge has invented a tube in which cathode rays (electrons) leave the tube. The tube is similar to other high-vacuum tubes in which electrons move from the cathode and jump to the anode. In this case, however, the tube is provided with a metal window of the proper thickness, the distance apart of atoms being such that the electrons discharged from the cathode can pass through, but molecules of

gases of which it is composed cannot penetrate it. In this way, the vacuum can be maintained within the tube. Robert Merrill, a journalist, writing for the magazine section of the Philadelphia *Public Ledger,* gives the following description of Dr. Coolidge's first demonstration of his tube before an audience:

Before an audience of distinguished scientists and interested students who sat spellbound in the darkened hall of the Franklin Institute in Philadelphia a few weeks ago, a slender, serious-looking man of 53 turned an electric switch—that modern prototype of the magician's wand. Immediately there followed a sharp crackling sound, and, in the darkness, a purple, fan-shaped haze spread in a radius of about eighteen inches from a curious apparatus the operator controlled. The glow was focused on a small piece of lime, as big, perhaps, as a man's fist. Under its power the mineral became luminous, red-hot apparently, until it, too, glowed like a live coal. Calmly then, indifferently, it seemed, the operator with unprotected fingers picked up that glowing mineral and handed it to the nearest spectator. It was cold—stone cold—yet it still glowed brightly as what looked like heat waves played over its luminous surface. A burst of applause followed the shocked surprise at that demonstration, and Dr. William D. Coolidge, assistant director of the Research Laboratory of the General Electric Company at Schenectady, bowed to that tribute to his new type of vacuum tube which can throw the magic cathode ray into the open air, there to accomplish new marvels of science.

This was one of the spectacular, and, to the scientist, amazingly important accomplishments of the new tube. Under its rays acetylene gas has been changed into a solid which no one thus far has been able to dissolve or analyze; castor oil has been made into a solid; negative electric charges have been imprisoned in certain substances; bacteria and fruit flies have been killed in a fraction of a second; clear pure quartz has been streaked and clouded with purplish hues; interesting effects have been obtained on the living tissues of both animals and plants.

To the lay mind many of these things may or may not seem insignificant. To the scientists, however, they open wide vistas, suggesting the possibility of new fields of research thus far almost untouched. One has, in fact, called it the outstanding scientific accomplishment of the last quarter century.



Courtesy General Electric Co.

COOLIDGE AND THE COOLIDGE TUBE

Dr. W. D. Coolidge, of the General Electric Company, is the inventor of the cathode ray tube, which allows electrons to escape into the air through a metal partition at the end of the tube.

Dr. Coolidge himself is reluctant to discuss the future possibilities of the ray except to express a hope that it may be of value in the treatment of diseases. But others who have watched it have

not hesitated to speculate on its potentialities as a possible cure for cancer, as an agent of transmutation, as a producer of new substances as yet unknown to man. Already it is known that the device will produce as many beta rays as can be obtained from a ton (about $100,000,000,000 worth) of radium, of which there is less than a pound in the world.

How are these wonders accomplished? What does the tube do?

As explained by scientists, Dr. Coolidge, by the new cathode tube, is able to control billions of electrons (particles of electricity believed to be the basic units of all matter) traveling at the rate of 150,000 miles a second. This stream he projects through a thin metal window in the tube into the open air. When it is directed against solids, gases, and liquids, the speeding electrons cause collisions which disorganize the combinations of the atoms which compose the targets and cause certain little-understood changes.

The cathode ray itself consists of a pear-shaped glass tube with a wire sealed in each end. The interior of the bulb is a vacuum. When the wires are connected outside the bulb to a source of high direct-current voltage, a stream of electrons flows from one to the other through the vacuum. The wire from which the stream starts is called the cathode and the other the anode. These electrons or negatively charged particles, coming from the cathode are called cathode rays. Voltages between the two wires in tubes of the earliest type varied from a few hundred up to thirty or forty thousand, and within these first tubes were observed the effects of the negatively charged particles upon objects placed in their path. Dr. Coolidge in his recent experiments has used a voltage of 350,000 and hopes in later tests to increase it.

The cathode rays themselves are not new in science. But it was not until the perfection of the Coolidge tube that it was possible to produce them in such quantities as to kill bacteria and insects and cause other extraordinary effects. In the older X-ray tubes the electrons from the hot filament are driven against a heavy tungsten "target" from which comes the secondary radiation called X-rays. In the new cathode ray tube, which resembles the X-ray tube, the electrons of cathode rays are driven instead against the thin nickel window which they penetrate and thus get outside the tube into the air.

This is possible because of comparatively recently learned facts concerning the construction of matter. What the layman regards as a solid substance, it would seem, is to the scientist a group of

atoms, each atom in itself a sort of solar system with a sun and planets. The empty regions between the "sun" and "planets" occupy more space than they do, so that the greater part of the volume that seems filled by a solid body is really unoccupied.

In the window of the cathode ray tube, the cathode rays, which travel as fast as 150,000 miles a second, pass between the parts of the nickel atoms and out into the open air. The air itself cannot get into the tube because the atoms of oxygen and nitrogen are about the same size as those of the window and are therefore too big to squeeze through the small spaces. One of the most difficult features met in the construction of the tube was the fastening of this small window of nickel, three inches in diameter and five ten-thousandths of an inch thick, to a glass tube so that no air could leak around it. But Dr. Coolidge succeeded and produced his interesting results.

With the cold caution of the scientist Dr. Coolidge is reluctant to speak of the potentialities of his new tube. Of what it has actually done he will speak. He was willing, for example, to discuss many of the experiments obtained in his Schenectady laboratory before the tube was exhibited in Philadelphia.

"With a specially designed hot-cathode, high-vacuum tube, it has been found possible to operate with high voltage, using a window as large as 8 cm. in diameter," he said. "The general design of this tube would seem to permit of the use of still larger windows and higher currents.

"The maximum range of the electrons in the air in front of the window has been measured approximately by the luminescence of lime.

"Calcite crystals, upon being rayed, fluoresce strongly in the orange and remain highly luminous for several hours after raying.

"Many liquids and solids undergo marked chemical changes under the influence of the high-speed electrons. For example, castor oil not only changes rapidly to a solid material, but crystals of cane sugar turn white in color and, upon subsequent gentle heating, evolve considerable quantities of gas. An aqueous solution of cane sugar becomes acid to litmus upon being rayed.

"The effect on organized tissues is very pronounced, as may be seen from the following examples:

"When a portion of the leaf of the rubber plant is rayed with one milliampere, for as long as twenty seconds, the rayed area becomes immediately covered with white latex, as though the cell

walls had, in some way, been ruptured. An exposure of as little as .1 milliampere for one second produces a visible color change with subsequent drying out of the rayed area to a depth corresponding to the penetration of the rays.

"The ear of a rabbit was rayed over a circular area 1 cm. in diameter for .1 second. Within a few days the rayed skin became deeply pigmented and the hair came out. It was not until seven weeks after the treatment that new hair appeared.

"A second similar area was rayed with 1 milliampere of current for one second. After several days a scab formed over the rayed area and a few days later the scab came off, taking the hair with it. Two weeks later a profuse growth of snow-white hair started and soon became much longer than the original gray (drab-colored) hair.

"A third area on the ear was rayed with 1 milliampere for fifty seconds. In this case a scab developed on both sides of the ear and these scabs later fell out leaving a hole in the ear. The periphery of this hole was at first void of hair but is now covered with a growth of snow-white hair.

"Fruit flies, upon being rayed for a small fraction of a second with one milliampere, instantly showed almost complete collapse and in a few hours were dead.

"Bacteria have been rayed and an exposure of one-tenth second has been found sufficient to kill even high-resistant spores.

"The phenomena of luminescence, phosphorescence, thermoluminescence and change of color which take place as a result of electron bombardment from the tube are very striking and easily demonstrated. . . ."

Born at Hudson, Mass., in October, 1873, Dr. Coolidge showed his scientific bent at an early age. In 1896 he was graduated from the Massachusetts Institute of Technology with the degree of bachelor of science. Then he continued his studies abroad, winning his Ph.D. at the University of Leipsic. He was assistant in physics at Massachusetts Tech., and later instructor in physical chemistry and assistant professor of chemical research. In 1905 he went with the General Electric Company, where he rose to his present office of assistant director of the research laboratory.

The present tube is by no means Dr. Coolidge's first outstanding invention. His work was largely responsible for the Mazda lamp, with its tungsten filaments. He is also the inventor of the Coolidge tube, the standard apparatus now in general use for the treatment

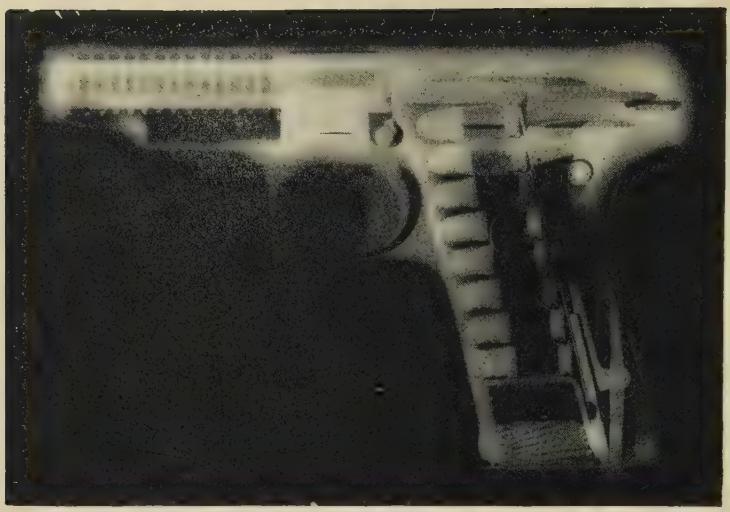
of cancer and for X-ray photography. It was for this that Dr. Coolidge was awarded the Howard M. Potts Medal by the Franklin Institute in Philadelphia on the evening when he made his first public demonstration of the new cathode tube.

TWENTIETH CENTURY ALCHEMY

Studying the peculiar behavior of elements which are undergoing spontaneous transmutation is interesting. Being able actually to produce transmutation is even more extraordinary. The alchemists strove to do this without any degree of success, because they were using hit-or-miss methods. Modern science has succeeded in bringing about transmutation in a very few cases, not for the purpose of transforming lead into gold, but with the idea of studying the structure of the elements.

Within the past half-dozen years, a number of transmutations have taken place in the chemical laboratory. Phosphorus, for example, has been converted into silicon and hydrogen. Aluminum has been transmuted into magnesium and hydrogen.

Dr. Adolf Miethe, a German scientist, in 1924 believed that he had prepared gold from mercury in a mercury-quartz lamp. The truth of this has been debated by scientists both pro and con. Some, who doubt whether the gold that Dr. Miethe produced actually came from the mercury by transmutation, point out that mercury usually contains gold as an impurity. Be this as it may, the comparative atomic structures of mercury and gold are such that the former might be converted into the latter if a way could be found of knocking off a few protons and electrons from each atom. The experiment, if it ever has been or will be performed, however, will probably have no practical applications, since the expense involved will be so great that the gold produced will cost many times the market price of this metal.



RADIOGRAPH OF A GUN

The X-ray can even penetrate metal, and enables us to see through things which before were entirely opaque.

CHAPTER XXII

SEEING THROUGH STUFF

The erthe seemyd me al clere and transparant soo that i myght see clearly all that was withyne.

—Caxton, 1413

MAN has made such remarkable progress in his mastery of materials that now, besides being able to produce innumerable substances not occurring in nature, he can see "through" quite a number of the substances he uses.

The ordinary light ray, as is well known, does not have the power to penetrate opaque objects. But the X-ray, discovered by Wilhelm Konrad von Roentgen in 1895, reveals many things invisible to the eye. The paragraphs below, taken from a publication issued by the Victor X-ray Corporation, portray the high lights of this interesting discovery.

At the time Professor Roentgen was making his experiments, he had available the following essentials for the production of the X-ray:

An air-pump, as first made by Otto Von-Guericke in 1650, for creating a vacuum.

A high tension electric current, as first produced by Faraday in 1838, to send through this vacuum.

A fluorescent screen, consisting of a deposit of barium platinocyanide crystals on cardboard, used by physicists in previous investigations of ultra-violet light, having found that these crystals had the property of giving off visible light while in the path of an ultra-violet beam.

Geissler, in 1859, studied the effect of passing a high tension current through a vacuum tube, but the degree of vacuum necessary for the production of the X-ray was not obtained until Herman Sprengel, in the year 1865, invented the mercury air pump, which offered a means of producing high rarefactions with comparative rapidity.

Physicists now began in earnest the study of electrical discharges in rarefied gases. Sir William Crookes, in 1875, exhausted tubes to the required degree of vacuum for the production of the X-ray, and he undoubtedly produced the X-ray at that time, although unaware of it. It remained for Wilhelm Conrad Roentgen to discover that the rays emanating from a high vacuum or Crookes' tube, when a high tension current is sent through it, would penetrate objects opaque to ordinary light and would affect the photographic plate. The accompanying figure illustrates the type of tube with which Roentgen discovered X-rays. This glass bulb was pumped to a high degree of vacuum. The anode and cathode, sealed within the tube, are the terminals offering a means of passage of the high tension current through the tube. If the tube were a complete vacuum, i.e., to the exclusion of all gases, there would be absolute resistance to the passage of electric current; therefore, in this type of tube the gases present were depended upon to convey the high tension current from cathode to anode. The passage of this current across the tube terminals (from cathode to anode) is known as the cathode stream of electrons. These so-called electrons travel at such a tremendous velocity that the resulting impact on the target of the anode causes that invisible light, X-ray, to be produced.

Following Roentgen's discovery there were numerous further developments which contributed to the making of better designed gas tubes, until they soon became standardized pretty much to the same general form.

But the gas tube even at its best was an uncertain factor in

much of the work that it was called upon to do in the routine work of the X-ray laboratory. It had periods of "crankiness," and while it might be functioning perfectly one day, it would be found unfit for the same purpose next day. In other words, it could not be depended upon to operate consistently. In the day of the gas tube, therefore, the roentgenologist had to be equipped with a large number of gas tubes, each with its peculiar characteristics, and which meant an investment of considerable amount. Obviously, a universally standardized technic was quite impossible under the circumstances.

It was in 1913 that Dr. W. D. Coolidge announced the tube which bears his name, and was developed by him in the Research Laboratories of the General Electric Company at Schenectady. It marked one of the most important advances in X-ray science.

Dr. Coolidge had discovered that an X-ray tube could be made to operate with great constancy if the cathode consisted of glowing tungsten and if the vacuum in the tube were made as perfect as possible. Such a tube can be operated continuously, and still show constant characteristics.

When the filament is heated there is an emission of electrons which, when the high voltage current from the X-ray machine is placed across the tube terminals, serve as a medium for carrying the X-ray current through the tube, i.e., from cathode to anode. The speed at which these electrons travel across to the anode is determined by the amount of voltage impressed. If 60,000 volts is impressed, the electrons will travel at an approximate speed of 82,000 miles per second, and the resulting tremendous impact on the tungsten target in the anode produces the X-rays. The penetrating power of these X-rays corresponds to the speed of these electrons at impact, and this speed may be varied at will by the amount of voltage impressed across the tube terminals. Because of this simplified control and consistent operation, the Coolidge Tube is now the universally accepted standard for all X-ray work.

AN INTERVIEW WITH ROENTGEN

In George W. C. Kaye's book on X-rays, the author gives in the appendix the following interview which Sir James Mackenzie Davidson had with Professor Roentgen shortly after the discovery of X-rays:

While traveling on the Continent in 1886 [Sir James wrote], I made a pilgrimage to Würzburg, and called at Professor Roentgen's house in the evening, and was kindly granted an appointment for the following morning. I presented myself about 11 A.M. and was shown into a laboratory which contained a coil and a small cyclindrical-shaped X-ray tube. Professor Roentgen, a tall man with dark bushy hair, a long beard, and very kindly and expressive eyes received me cordially. He could not speak much English; I was still worse at German. However, by means of English and some Latin we made ourselves intelligible to one another. He excited the tube and showed me various shadows on a fluorescent screen. . . . I asked some blunt questions as follows:

Q. What were you doing with the Hittorf tube when you made the discovery of the X-rays?

A. I was looking for invisible rays.

Q. What made you use a barium platino-cyanide screen?

A. In Germany we use it to reveal the invisible rays of the spectrum, and I thought it a suitable substance to use to detect any invisible rays a tube might give off.

He then detailed how he had covered up the Hittorf tube with black paper so as to exclude all light, and had the screen (which was simply a piece of cardboard with some crystals of barium platino-cyanide deposited on it) lying on a table 3 or 4 meters from where the covered tube was situated ready to be used. He excited the tube to ascertain if all light was excluded. This was so, but to his intense surprise he found the distant screen glowing brightly!

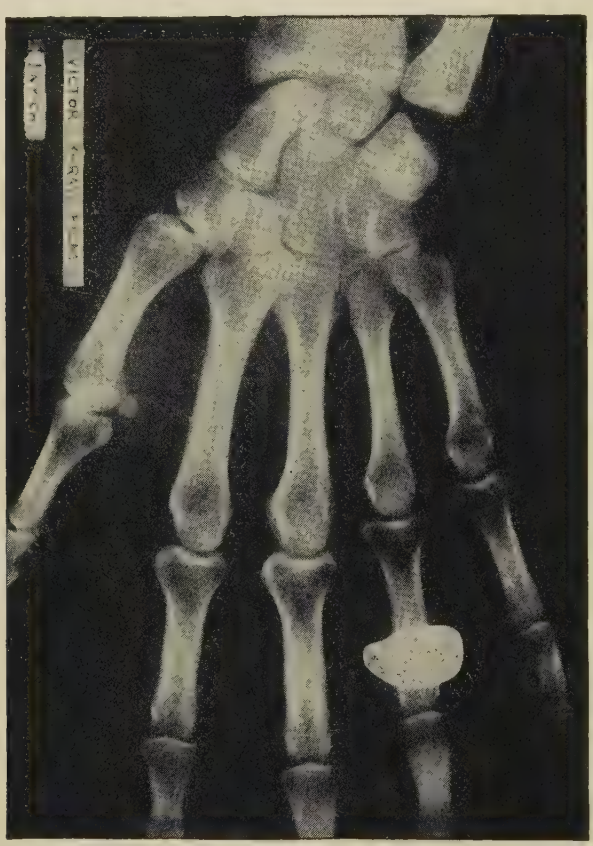
I asked him, "What did you think?" He said very simply, "I did not think, I investigated."

Incidentally he told me that he had taken a photograph through a pine door which separated two of his laboratories. On developing his negative, he found a white band across it, which, he ascertained, corresponded to the beading on one of the door panels. He stripped the beading off, and found the band of shadow was due not to the increased thickness of the wood but to the "plumbum" (white lead really) the doormaker had employed in attaching the strip of wood.

THE X-RAY IN MEDICAL PRACTICE

Shortly after Roentgen's discovery of X-rays, the possibility of using them as an aid to the physician became apparent.

X-rays penetrate opaque bodies with unequal intensity. Lead, for example, is relatively impermeable to this form of energy. Calcium is penetrated to a higher degree than lead, but our



AN X-RAY PICTURE BY TELEPHONE

This is the first radiograph ever transmitted by telephone wire.

bones and teeth (which are compounds of calcium) serve as a sufficient barrier to these rays to permit photographs being taken of the bones and teeth of the body. Carbon, hydrogen, oxygen, and nitrogen, the elements of which our flesh is composed, on the other hand are relatively transparent to these rays.

No modern hospital to-day is operating without its X-ray department. Every physician, surgeon, and dentist depends on the X-ray for diagnosis and prognosis in a large portion of his cases. There is practically no region of the body that is not subject to a searching examination for the detection of disease or injury at one time or another, and the physician can cite many cases in which the treatment of some conditions would have proved complicated, and the outcome very much in doubt, had he not had available the X-ray as an aid.

RADIOGRAPHY

One of the very common uses of the X-ray in the hands of the physician and surgeon is in the treatment of fracture cases. Should you have the misfortune to break a leg or an arm, in fact any bone in the body, the physician to whom your case is entrusted would resort immediately to the X-ray as a means of determining the extent of the injury. His findings are usually read from a photographic film—so-called radiograph. Any one at all familiar with ordinary camera photography will readily understand this step in the procedure. The photographic film, in a suitable light-tight holder, is placed under the injured part of the patient, while the X-ray tube is focused above. The X-rays emanating from the tube penetrate the part of the body under observation, and finally reach the emulsion of the film, recording the shadows and various densities much the same as ordinary light acts on the film in your camera.

With the radiograph before him showing the exact nature of the fracture, the physician can now intelligently and effectively set the fracture. After placing the limb in a cast, he again resorts to the X-ray as a means of checking up, to determine whether correct setting of the fracture has been accomplished. The result is that in the treatment of most fractures in present-day practice, the X-ray insures against impaired functions of

the injured parts such as our fathers so often suffered simply because the X-ray was not known.

FLUOROSCOPY

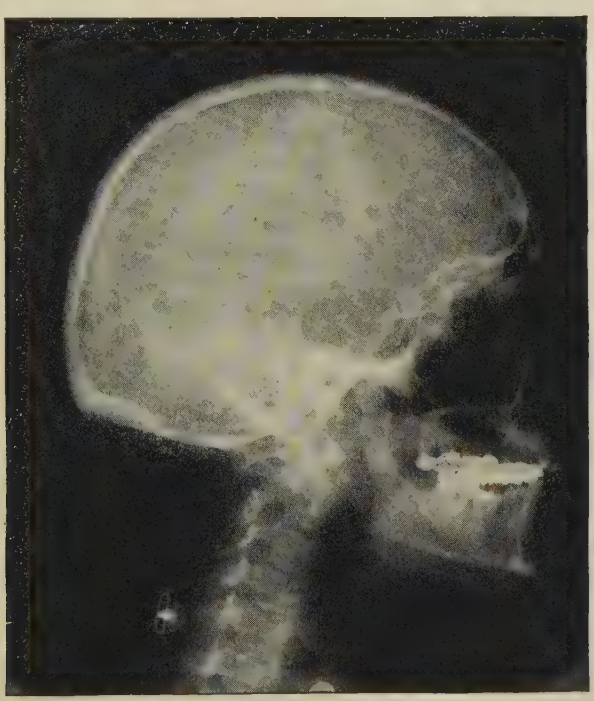
Fluoroscopy is another form of diagnosis with X-rays. This is done by means of a fluorescent screen, consisting of a cardboard surface treated with chemicals which fluoresce, i.e., give off visible light, when exposed to the action of X-rays. With the patient placed between the X-ray tube and the fluorescent screen, the X-rays pass through the body and act upon the chemicals on the screen, causing them to fluoresce to the degree of intensity of the rays when they reach the screen, this of course governed by the density of the bones and tissues of the body. By this means the physician studies the lights and shadows on the fluorescing screen, watching the heart beats and the movements of other internal organs.

If a physician wishes to study a patient's intestinal tract, the patient is given a barium meal (barium is opaque to the X-ray), and after the required number of hours for this meal to pass into the intestinal tract, the examination is made. The mass of barium salt distends the intestines and, being opaque to the rays, appears as a solid mass on the radiograph or fluorescent screen. Obviously, if there are obstructions present, the shadows will reveal them. Often the X-ray diagnosis is the deciding factor to a surgeon considering the question as to whether or not to operate.

Many other abnormalities in the body, such as tuberculosis, cancer, and the various tumors, are revealed by the use of a fluorescent screen and X-rays.

By the same means the physician can locate or detect foreign bodies. Almost every one has seen at some time or other X-ray reproductions showing pins, safetypins, nails, coins, buttons, hairpins, pipe stems, tooth plates, etc., lodged in the trachea or in parts of the alimentary tract. These foreign

bodies, which are accidentally swallowed, cause a great deal of alarm. With X-rays, however, the surgeon soon learns whether an immediate operation is necessary. If not, he can watch the progress of the foreign body from day to day, sometimes hour to hour, and in a great number of these cases sees the final expulsion of the article without surgical intervention.



RADIOGRAPH OF A HEAD

THE VALUE OF X-RAY IN DENTISTRY

Dr. Clarence O. Simpson, an oral diagnostician and author of a textbook on *The Technic of Oral Radiography,* has written the following regarding the utility of the X-rays in dentistry:

Periodic X-ray examinations of the teeth and jaws are essential to efficient dental and health service. Intelligent people appreciate

and obtain the advantages of dental examinations two or three times each year, but the usual clinical examination is inadequate in being limited to the visible surfaces of the teeth and the superficial tissues of the mouth.

The chronic infection at the end of tooth roots which contributes to grave systematic diseases rarely gives warning by local symptoms or visible changes. Decay in the contact surfaces of teeth and under repairs may invade the tooth pulp before being discovered by instrumental examination. Pyorrhea alveolaris may progress until marked destruction of the bone occurs without being observed in the customary dental inspection. Cysts develop around misplaced teeth until the resulting deformity is evident before being suspected. These critical disturbances and many other significant dental conditions are disclosed in a thorough X-ray examination by one qualified correctly to interpret the evidence.

The X-ray examinations of the teeth should be made at intervals of one to three years, depending upon the susceptibility of the individual to dental disorders and the amount of reparative work in the mouth.

X-RAY THERAPY

The use of the X-ray therapeutically began years ago in the treatment of certain forms of skin diseases with marked success. This is known as superficial X-ray therapy.

Since the advent in 1921 of the 200,000 volt Coolidge tube, however, interest in the treatment of deep-seated malignant diseases with X-rays has been greatly stimulated, and while specialists prefer to wait for a period of years before stating definitely the degree of success realized, they are much encouraged with the results obtained thus far, and are quite optimistic over the possibilities of eventually controlling cancer, that much dreaded disease which is so widely prevalent to-day and which has baffled medical scientists for ages.

THE X-RAY IN MUSEUM RESEARCH

Several years ago the Educational Department of Victor X-ray Corporation set out to determine to what extent the

X-ray might be valuable in museum work. After an investigation of the possibilities, C. D. Davies, director of the Field Museum of Natural History, Chicago, offered to provide all the facilities of that institution for carrying out this work.

The group of subjects selected for the preliminary work consisted of mummies, the Field Museum having in its collection about fifty Egyptian, seventy-five Peruvian, and a few American mummies. Most of these are enclosed in their original wrappings.

Obviously the use of the X-ray in the study of mummies offers a great advantage in that so much information can be obtained without material injury to the subject. Were all the wrappings to be removed, the body would rapidly decompose, which would mean the sacrifice of a valuable specimen. As a result of a considerable number of radiographs made on this group of mummies, the following reasons for continuing the work have been found:

1. To determine whether or not a body is really enclosed.
2. To aid in determining the age of the individual.
3. To aid in determining the sex of the individual.
4. To aid in determining the period or dynasty during which the individual lived and died.
5. To aid in determining the presence of trinkets or ornaments of metal, bone, pottery, clothing, food, or other opaque substance.
6. To aid in the study of bone pathology that may be present.

These mummy radiographs reveal the fact that fractures were exceedingly common with the Egyptian and Peruvian. The causes of these fractures and whether they occurred before or after death will probably never be known.

This preliminary work has convinced the directors of the Field Museum of Natural History that there is an abundance of material available for X-ray work that will prove of inestimable value to the scientific world for various phases of

research; not only as it pertains to the history of mankind for thousands of years back, but also on many other subjects such as animal life, insects, fish, reptiles, seeds, seed pods, and flowers, also geological formations, including fossils and minerals.

A complete X-ray equipment, especially adapted to museum work, has since been installed in the Field Museum, and a staff

SEEING THROUGH A WATCH BY MEANS OF X-RAYS

of archæologists, anthropologists, radiologists, and technicians has been organized to conduct the work of this department.

THE X-RAY IN INDUSTRY

In recent years the use of X-rays in the examination of metals has been given a great impetus through the development of a higher power Coolidge tube, capable of handling 200,000 volts. As pointed out in the first part of this chapter, the

more dense the material, i.e., as the atomic weight increases, the more powerful must the X-ray be to penetrate it. And as the voltage is increased in the X-ray tube, the resulting radiation is increased in its power to penetrate a given substance.

Dr. H. H. Lester, Research Physicist at Watertown Arsenal, Watertown, Massachusetts, in an article, "X-Ray Tests Applied to the Problems of the Steel Foundries," presents the following abstract:

> X-ray tests with collateral analyses indicate that defects in steel castings fall into a relatively few classes traceable to definite and simple causes, most all of which are removable. When defects are detected by X-ray examination and corrected by changing casting technique they tend to stay corrected. It is possible by this method to eliminate from 75 to 90 per cent of the major defects in steel castings.
>
> Metal sections up to 3 inches in thickness may be examined. Where the value of the product warrants it, X-rays may be used to test each individual casting. In other cases casting technique may be developed that will produce sound castings.

In another article, "Using X-Rays to Detect Hidden Dangers in Plant Equipment," the authors point out how defects in castings, as used in high-pressure oil stills and overlooked in inspection by the usual method, are easily seen in the radiograph.

Needless to say, the use of the X-ray suggests itself in thousands of ways industrially, where stress on metals involves certain hazards—it may be a vital part of an automobile or other form of vehicle, or of manufacturing machinery. The radiograph on page 432 shows the fine definition now obtainable in metal radiography when using modern high power equipment. That there will be a widely increasing application of the X-ray industrially is predicted by experimental engineers in the leading industries.

THE HERBALIST

Doctors of ancient and medieval times used herbs as their chief medicines. They carefully tended these in their gardens and stored them in well-built cellars.

CHAPTER XXIII

MEDICAL STUFF[1]

A certain stuff, which, being taken, would seize
The present power of life.
—SHAKESPEARE

I DRESSED him, God healed him. I sent him home merry with a wooden leg."

Thus Ambroise Paré describes a "successful" operation that he performed in 1552 on a man suffering from a cannonball wound. Paré was a French barber who, according to the custom of the time, also practiced surgery, bleeding, and leeching. He entered the medical department of the French army and rose to the rank of army surgeon because of his skill in amputations. When wounded soldiers were placed under his care, he performed operations and amputations without administering anæsthetics, and without the use of antiseptics or cauterizing agents. Those who were subjected to this treatment might well be merry if no worse fate than a wooden leg fell to their lot.

On December 20, 1923, a beating human heart was exposed by Doctors Cutler and Levine of Boston. A delicate knife was thrust through the wall of the heart, and the opening between an auricle and ventricle was enlarged. The patient was a twelve-year-old girl who was suffering from inflammation and resulting thickening of a valve in the heart, and had been confined to her bed for months by this malady which had previously been considered incurable. The little girl recovered from the operation, however, and was able to be up and active in a short time.

[1] The chapter was written by Elizabeth Long Clair, a former student of the author.

This was the first time in medical history that successful surgery within the human heart had been considered possible.

Compare the operations of Paré and the other barber-surgeons of his day with those of the most highly skilled surgeons of our own generation! The former were done by mere members of an unskilled trade; the latter by men highly trained in the pure and applied sciences.

The science of chemistry is one of the most important contributions to the recent remarkable advances that have been made in surgery and in medicine generally. It has shown the actual processes taking place in the body and has furnished materials needed to alleviate suffering. These materials range all the way from the finest of alloy steels used in making the blades of the most delicate surgical knives to anæsthetics and antiseptics, which make operations painless and without danger of infection. They also include such widely different substances as glass of the finest quality for lenses, disinfectants for household uses, fumigants for preventing the spread of disease, drugs for curing disease and allaying pain, silver salts for making the sensitive parts of an X-ray plate, and a host of other things.

ANCIENT SURGEONS

Physicians and surgeons from the earliest times have been limited in their practice by the materials available for their various needs. Thus, if an Egyptian physician of 4000 B.C. wanted to perform a minor surgical operation, he was obliged to use a flint knife, because metals had not yet been discovered and brought into use. The chemist of to-day has found out how to extract more than half a hundred metals from ores in which they had previously been hidden away in nature. These he can adapt to almost any use required by medical science. By his accomplishments in alloying and tempering but one of these—iron—he has given the surgeon instruments keen and

fine enough to be used in operating successfully upon the human heart.

Although the physicians of ancient Egypt were limited in their activities by the extremely small number of materials at their disposal, they nevertheless worked out an elaborate system of medical ethics. As Herodotus explains, they practice medicine "on a plan of separation," each physician treating but one disorder and no more.

One reason why the physicians and surgeons of ancient civilized countries were so highly specialized was probably that penalties were prescribed by law for failure to treat cases properly. The requirements were so exact in this regard that it was dangerous for a man to try to treat more than one kind of ailment. The Code of Hammurabi, for example, listed the rights and duties of the physician in Babylonia in 2080 B.C. According to this code, a physician who operated on a severely wounded freeman with a bronze latchet and saved his life received a specified sum of money. If, on the other hand, he caused the man's death, he forthwith lost his own hands. If the unfortunate physician caused the death of a slave, he then was required to restore a slave of equal value to the owner.

ANCIENT IDEAS OF ANATOMY

The knowledge possessed by ancient Egyptian and Babylonian physicians spread to Greece, the earliest of European civilizations. Æsculapius, father of Grecian medicine, was a mythical character who was supposed to have received his instruction in the healing art from Chiron, the celestial professor who was half man and half horse. Æsculapius is supposed to have passed his knowledge of medicine on to Plato, the philosopher and writer on medical subjects, who lived from about 428 to 348 B.C. Although Plato was the greatest thinker of his time, he was extremely inaccurate in his ideas of anatomy, and his knowledge of curative agents was limited to

that of herbs. The following statements are taken from his description of the human organism:

> The heart is the origin of the blood vessels, and the seat of the mind, receives through them superior commands of the superior soul. The lungs which receive through the trachea a portion of the drink in addition to the air, serve to cool off the heart. The spleen furnishes an abode for the impurities of the blood. The intestine is long and tortuous in order that the food may remain longer therein, so that the mind may not be disturbed too often in its contemplations by the renewal of nutriment necessitated frequently by greater shortness of the gut. Death is occasioned by the separation of the soul from the marrow.

Plato's teachings concerning the activities of the body now seem absurd. In an age when there was no knowledge of chemical processes and no means of making a minute study of the structure of cells and tissues, however, there is small wonder that he failed to comprehend all that went on inside the human organism.

The medical knowledge possessed by the Greeks passed on to the Romans and was disseminated by that race throughout much of the rest of Europe. The advent of the Middle Ages, however, found European surgeons still performing crude operations, and doctors still relying entirely upon herbs as their source of medicine.

HERB DOCTORS

The doctors of Europe who lived during the Middle Ages devoted almost all of their time to the study of the medicinal properties of herbs. They left surgical operations to the barbers, who were rated lower socially. In order that they might be assured of having perfectly reliable plants from which to make their brews and distillations, they almost always insisted upon collecting their own specimens, and frequently they kept their own gardens. They compiled lengthy treatises,

called herbals, in which they gave names, descriptions, locations, properties, pictures, and "vertues" of all the plants known. There was not a single plant in the list that was not credited with some medicinal value. The plants thought to possess "vertues" ranged all the way from those deemed to be "against drawing together or awry of the sinews" to those supposed to "ripen or help an old cough." Lettuce was credited with even more virtues than those which modern scientists assign to it, and onions were thought to have a helpful effect both on the body and the disposition.

Although doctors of the Middle Ages pinned their faith chiefly on the administration of simples, they also began to make a rather general practice of bleeding for all maladies that presented serious aspects. As recently as 1800, Dr. I. Lettsom, a successful and benevolent English physician, wrote the following:

> When patients come to I,
> I physics, bleeds, and sweats 'em;
> Then—if they choose to die—
> What's that to I—I let's 'em.

Although this was written in a spirit of fun, it represented perfectly the attitude of the times. It showed further how lacking in resourcefulness the physicians of former ages were. This lack of resourcefulness was largely the result of the meager knowledge of chemical processes which they possessed, and the limitations placed upon them by a lack of materials suitable for their needs.

CHEMISTRY AND MEDICINE

The first effort to adapt the methods and theories of the early chemists to medical science was made early in the sixteenth century by Hieronymus Brunschwygk, a surgeon of Strassburg, Germany. In 1500 he published a volume called *The Book of the Art of Distilling Simples.* About twenty-five

years after the publication of this book, Paracelsus, a Swiss scientist, whose real name was Theophrastus von Hohenheim and who lived from 1493 to 1541, inaugurated a revolutionary movement which resulted in the final overthrow of medieval slavery to ancient traditional authorities. While he was practicing medicine and giving instruction in the University of Basle, he publicly burned the works of the learned men of the time who taught witchcraft and compacts with the devil. He declared openly that the universities that fostered such ideas had less experience than his beard, and that the down on his neck was more learned than all authors.

Although many of Paracelsus' immediate followers misinterpreted some of his teachings, his work ultimately led to excellent results. It was he who recognized chemistry as the necessary adjunct to medical science. His teachings led to the rise of the science of iatrochemistry, or the application of chemistry to medicine. This branch of science is frequently called Paracelsian pharmacy or pharmacology.

The first university professor of pharmacology was Johann Hartmann, a German and a follower of Paracelsus, who occupied the chair of iatrochemistry in the University of Marburg. The introduction of a science in which medicine and chemistry could be developed hand in hand was the first great step toward the elimination of guesswork for the treatment of disease.

Medical investigation since the time of Paracelsus has come to depend more and more upon chemical research. All of the institutions devoted to the study of health and disease now investigate their cases from the chemical as well as the biological standpoint.

HIGH-PRICED DRUGS

Chemistry has made, as one of its most important contributions to medical science, the discovery of a large number of

materials which may be used by physicians to allay suffering and restore humankind to good, sound health. Drugs in olden times, besides being few in number and of doubtful medicinal value, were so expensive that they were beyond the reach of common people. There were no cut-rate, syndicate, chain drug stores in those days, from which one could purchase everything from bromo-seltzer to a lettuce sandwich. Thus balsam of Gilead was quoted in ancient Rome at $187 a pound, nard leaves at $14 a pound, and oil of the folio malabathri at $75 a pound. The chemist of to-day has prepared a greater number of medicinal products than were ever dreamed of by the drug-sellers of ancient Rome, and these are now available at prices that are within the reach of all.

SLEEP-PRODUCING STUFF

Anæsthetics are man-made products which have contributed to the alleviation of suffering. These are volatile substances administered by inhalation and producing in the patient a state of insensibility to pain. The duration of the effect of these compounds may be easily regulated. Chloroform, ether, propylene, and other chemical substances have been found to be effective agents for producing anæsthesia.

Even pulling a tooth need not be the trying ordeal that it once was, because of the anæsthetic properties of nitrous oxide, a chemical product. It was the chemist Sir Humphry Davy who in 1800 first found that this substance had anæsthetic qualities.

DAVY'S NOTABLE CONTRIBUTION

While employed as an assistant to Dr. Beddoes, the chief scientist on the staff of a pneumatic institute in Bristol, Davy discovered the anæsthetic properties of nitrous oxide or laughing gas. This discovery brought him into prominence and led

AN EXCITING EVENING AT THE ROYAL INSTITUTION

A member is being forcibly obliged to inhale some of the newly discovered nitrous oxide. Humphry Davy, the discoverer, is the lecture assistant at the right.

later to his engagement as lecturer at the Royal Institution of London.

It was at one of his early appearances at the Royal Institution that the anæsthetic properties of nitrous oxide were discussed for the first time before a scientific gathering. The lecturer of the occasion was Dr. Garnett, the president of the Institution. Garnett was assisted by Davy, who was still a very young man.

During the lecture, an argument occurred in which a certain Sir John Hippesley was forced to smell the "pleasure-giving air" against his will. In the accompanying cartoon, taken from a popular publication of the day, Humphry Davy is shown with the bellows from which the flask has just been filled with nitrous oxide or the so-called laughing gas. The figure standing near the door was intended to represent Count Rumford, a patron of the sciences and later a close friend of Davy's. In the audience are Isaac Disraeli, Lord Stanhope, Earl Pomfret, Sir H. Englefield, and other well-known men of the day.

In passing, it is interesting to note that Davy succeeded Garnett as president of the Royal Institution of Science of London, the greatest distinction that an English scientist could achieve in his day. He was later knighted for his remarkable contributions to science. Michael Faraday, another great scientist, began his career as Davy's laboratory assistant.

THE FIRST GENERAL ANÆSTHETIC USED IN AN OPERATION

Dr. Pearson, of Birmingham, England, discovered that ether is an anæsthetic. Dr. J. C. Warren, of Boston, confirmed his results in 1805.

On March 30, 1842, Dr. Crawford Williamson Long, of Georgia, performed the first authenticated operation with ether as a general anæsthetic. The man that he operated upon was James M. Venable, from whom he removed a tumor. Two months later Dr. Long removed a second tumor from

the same patient, again using ether. Dr. Long's account book is still in existence, and from it we find two tumor operations charged to James W. Venable on March 30th and June 6, 1842. On each occasion the patient was charged $2.00 for "exsecting the tumor," and 25 cents for ether.

Two years after Dr. Long's first operation, Dr. Horace Wells, a dentist of Hartford, Connecticut, underwent nitrous oxide anæsthesia. After a few ups and downs in the early application of this gas, it came to be used quite commonly in the dental profession.

In 1846, Dr. W. T. G. Morton, a dentist of Boston, used ether in a case of tooth extraction. In 1849 Dr. Morton anæsthetized a patient in the Massachusetts General Hospital for Dr. John Collins Warren. A tumor was removed from the patient. Because Dr. Long had not yet made his results public beyond his own immediate locality, the Massachusetts doctors were credited for a long time as being the first to use ether. Dr. Long's priority, however, has been definitely established.

CHLOROFORM

Chloroform was not used as an anæsthetic until after ether had come into fairly general use, despite the fact that it was discovered about 1831. This substance was prepared independently by three investigators—Dr. Samuel Guthrie, of Sacketts Harbor, New York; M. E. Soubeiran, of France, and Liebig, of Germany.

Dr. Guthrie made his discovery and placed a specimen of his product in the hands of Professor Silliman, editor of the *American Journal of Science and Arts,* in the late summer of 1831. An account of the discovery appears in the issue of the *American Journal of Science and Arts* for September 12, 1831. Accounts of the preparation of chloroform by the same method as that employed by Guthrie were given to the world simultaneously by Soubeiran and Liebig, in March, 1832. Soubeiran

published his results in the November issue of the *Annals de Chemie et de Physique,* which did not reach other countries until March because of the political disturbances of the time. Liebig's work on the subject came out in a March issue of a German publication. There can be but little doubt that neither of these scientists knew of the work of the other at the time when they sent their articles to the publisher, and that neither of them had heard of Guthrie's work in America.

The method used by these investigators for preparing chloroform was the distillation of chloride of lime with alcohol.

Guthrie called his newly discovered substance *chloric ether;* Soubeiran named it *ether bichlorique;* and Liebig used the term *chlorkohlenstuf* (chloride of carbon). Dumas, the noted French chemist, analyzed the substance in 1834 and determined that it consisted of one atom of carbon, one atom of hydrogen, and three atoms of chlorine to the molecule. He gave the substance the name *chloroform.*

DR. GUTHRIE, DISCOVERER OF CHLOROFORM

Dr. Samuel Guthrie, the first discoverer of chloroform, was born in 1782 in Brimfield, Massachusetts. He learned the profession of medicine from his father, who was a physician and surgeon. During the war of 1812 he acted as examining surgeon in the army.

At the close of the war he moved to Sacketts Harbor, New York, where he established a vinegar factory. In connection with the factory he built a laboratory, where he carried on various scientific investigations. One of the lines of investigation that he was interested in was the making of gunpowder. As a result of his work with powder, he developed a percussion priming pill which was well known to all sportsmen of a generation or more ago. The manufacture of vinegar, powder, and other chemicals came to occupy so much of Guthrie's time that he gave over his practice of medicine altogether. His

priming powder was used all over the United States and Canada, and his vinegar also had an extensive sale.

Even when prosperity smiled upon his enterprises, Dr. Guthrie continued to be a man of modest tastes, content to spend much of his time in his laboratory. During the last ten years of his life he was in poor health resulting from injuries he had received at various times while experimenting with his percussion powder. He died in 1848 at the age of 66 years.

The memoirs of Dr. Samuel Guthrie were written in 1877 by O. Guthrie, his grandson, through the invitation of the Historical Society of Jefferson County, New York. In these memoirs the facts relating to Guthrie's discovery of chloroform are told.

NOVOCAINE

The chemist has also made remarkable contributions in the field of local anæsthetics. Cocaine, a white crystalline substance, was first extracted from cocoa leaves in 1860. Soon after its isolation, it was found that if it were injected under the skin, it made the nearby parts insensible to pain. This made operations of short duration possible without subjecting the entire body to the somewhat poisonous after-effects of general anæsthetics. In many cases it proved unsatisfactory, however, and even deaths have been known to follow its use.

At this point the chemist entered the scene. After several unsuccessful attempts, he was finally able to analyze a sample of cocaine and to determine its chemical structure. The molecular structure proved to be quite complex, there being 43 atoms in all to the molecule. One corner of the molecule was found to be responsible for the anæsthetic property of the compound, while another part contained a group of atoms closely related in structure to the poisonous principle of hemlock. With the information gained by this analysis of cocaine, the chemist was in a position to make a synthetic product whose molecule should not contain the part responsible for its

poisonous action. Thus novocaine or procaine, an artificial product having all of the virtues and none of the vices of cocaine, was prepared. Beta-eucaine, apothesine, benzy-alcohol, and anæsthesine are also synthetic products with a local anæsthetic action. The chemist has made these as improvements upon the substances of similar character found in nature, and he has so reduced the price of substances of this sort that he has placed them within the reach of every one.

Because of the great assistance that the chemist has given the doctor by preparing satisfactory anæsthetics for use in dentistry and surgery, operations have become so common and so little fraught with danger that a person who has had an operation is no longer looked upon as somebody out of the ordinary.

REDUCING INFECTION

Operations by modern surgeons could not be carried on with nearly so much assurance of success, however, had antiseptics as well as anæsthetics not been developed. As in the case of anæsthetics, the need of antiseptics was present long before it was realized. As soon as the need was recognized by the surgeons, however, the chemist was ready to supply the necessary antiseptic agents.

During the Franco-Prussian War, the French lost 10,006 out of 13,173 amputations, because of gangrene. In civilian operations performed during this same period, surgeons were satisfied if no more than one-third to one-half of the operations performed proved fatal. Two out of three cases of compound fracture resulted in death.

About 1860 Joseph Lister, an English surgeon teaching in the University of Glasgow and practicing in the general hospital of that city, found that hospital a hotbed of septic diseases. People were crying out against the hospital method, and its abandonment was threatened. Lister showed that the hospital itself was not responsible for the state of affairs, but

ÆSCULAPIUS RECEIVING THE GIFT OF MEDICINE FROM THE MYTHICAL CHIRON

(From an ancient Grecian painting.)

that the operator, his instruments, and his assistants were spreading infection. By demonstrating that a very weak solution of carbolic acid could be used to sterilize the hands of the surgeon, his tools, and the very wound itself, he laid the foundation for antiseptic surgery. When the cause of infection became known, the chemist stood ready to prepare many antiseptic compounds that should satisfy the surgeon's needs. The use of sodium hypochlorite (Carrel-Dakin solution, introduced during the late war for the sterilization of deep wounds) is one of the triumphs of medicine and chemistry combined.

To-day every organ in the human body may be operated upon successfully without danger of infection. Even the head may be opened to remove tumors and foreign bodies, and for the treatment of abscesses and dropsy.

PASTEUR'S WONDERFUL WORK

Louis Pasteur, who lived from 1832 to 1895, a professor of chemistry at Lille, France, was the pioneer in the work that led to the establishment of the germ theory of disease. While trying to find out why substances fermented, he discovered that fermentation was accompanied by the growth of cellular bodies which proved to be living organisms. This led him to believe that diseases of man and animals might be caused by unknown living organisms. By working on this hypothesis, Pasteur found the specific germ that caused puerperal fever, and the one that caused hydrophobia. Physicians were able to cope with the former by the use of antiseptics. Pasteur himself brought the latter into the range of curable diseases by the development of a special vaccine. He succeeded also in finding the cause and remedy for many diseases common to animals. Thus a chemist working on a chemical problem came upon the discoveries that led to the establishment of a new science, bacteriology, and to a new theory of infectious diseases, the germ theory. The fact that glass, a chemical product, was

necessary for making the microscopic lenses used to study the living organism which Pasteur discovered is but another bit of evidence to show the dependence of medical science upon chemistry.

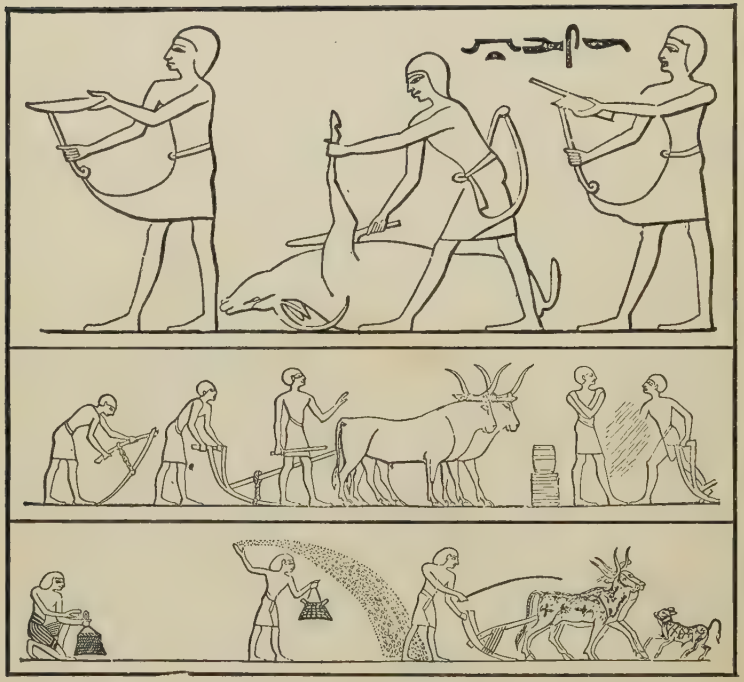
MEDICINES FOR EVERY ILL

Chemistry has made its contributions to medicine not only in surgical operations and in the treatment of infectious diseases, but also in the care of every illness that human flesh falls victim to. The medicinal materials which the chemist has prepared range all the way from tartar emetic, which is a remedy for dysentery, to epinephrine, which fortifies the hearts of old or weakened patients during operations. Quinine, a specific for malaria; arsenic compounds, used to destroy the organism which causes African sleeping sickness; compounds isolated from chaulmoogra oil, used for the treatment of leprosy; homatropine for the use of the oculist; codeine, a product from which the blessings and none of the curses of morphine may be derived; theobromine and theophylline, which are invaluable as diuretics; cinchophen, an alleviator of gout; adalin, a sedative which gives the minimum disturbances to the body; and luminal, a specific for epilepsy, are but a few of the drugs which the chemist has placed in the hands of the physician. He has prepared these either by isolating pure principles from the crude drugs found in nature, or by building up synthetic compounds absolutely identical with the natural compound, or by making entirely new compounds which are superior in properties to the natural.

The story of each drug prepared by the chemist is a romance in itself. The isolation and synthetic preparation of epinephrine (adrenalin) furnishes but one example. Physicians discovered a few years ago that the suprarenal glands, small glands embedded in the fatty tissue just above the kidneys, contained a principle which had a constricting action on the blood vessels. This principle proved to be a compound called

epinephrine, which finally was isolated from the glands of sheep in a pure form. The scarcity of the substance made its price prohibitive. The chemist came to the rescue, analyzed the compound, figured out its molecular structure, and then made an artificial product which was exactly the same as the natural in composition. The discovery of this process provided physicians with an abundance of the product which could be used to reduce loss of blood in cases of minor hemorrhage, to stimulate weak hearts during operations, to allay acute bronchial asthma, and to reduce bleeding in minor operations performed by the use of local anæsthetics.

From the ancient priest-doctor of Egypt, using implements of stone, to the modern surgeon, able to operate on the most delicate organs of the body, has been the advance of surgery. From fragmentary knowledge of the curative properties of a few herbs to exact knowledge of the composition and physiological effect of thousands of pure compounds has been the advance of medicine. The progress that has already been made in the preservation and restoration of health is truly wonderful. But wonderful as they are, they are only an indication of greater knowledge that the future may hold.



THE COW—THEN

Five thousand years ago the Egyptians used the cow as a farm animal and as a source of steaks and stews. They never thought of making handles for Boy Scout knives out of the horns, or extracts from the glands. But then, it would have done them no good if they had, since there was no steel for knife blades or for hypodermic needles.

CHAPTER XXIV

THE CHEMIST AND THE COW

There was an old woman had three cows,
Rosy and Colin, and Dun;
Rosy and Colin were sold at a fair,
And Dun broke his head in a fit of despair,
And that was the end of her three cows,
Rosy, and Colin, and Dun.
—Old English Rhyme

THIS poem undoubtedly does not tell the whole truth about what actually became of the old lady's three cows. There is little question that Rosy and Colin continued to be faithful animals even after they had changed owners, and that Dun was converted at once into beef, leather, and soap. Even in the Middle Ages, when this rhyme was written, the value of the cow, alive or dead, was too well appreciated to permit one to come to a useless end. Oliver Herford, the poet, said that the cow is the source of so many "boots and shoes, milk punches, Gladstone bags, and stews, and things too numerous to count" that he sincerely hoped the cow would last at least until his generation was past.

ANCIENT UTILIZATION OF COWS

That the cow has been the source of stews, boots, shoes, and milk beverages since very ancient times is shown by the many references to cattle in all literature. The ancient Egyptians raised cattle, and the Israelites depended upon these animals as a source of considerable part of their income. The old Hebrew word from which our word *cattle* is derived originally meant "possessions" or "wealth," which shows that these animals were one of the chief sources of wealth of this ancient

race of people. Thus in Genesis 13:2 it is said that Abraham was very rich in cattle, in silver, and in gold. Job's wealth likewise consisted in great part of herds, chiefly cattle. The ancient Greeks and Romans considered cattle as being so valuable that they used them as money before coins were invented.

STEWS AND HIDES

Long before the domestication of animals, the wild ancestors of domestic cattle were killed for food. Since the skins were removed during the dressing of game, it is no wonder that leather came to be used even in prehistoric times. Relics have been found which show that in the Stone Ages hides were treated with lime or with the acrid juice of some desert plant to remove the hair, and that the skins were cured to prevent them from decaying. There were two methods for preserving leather in very ancient times. The oldest of these consisted of rubbing the skin with fat. This treatment probably resulted from the fact that prehistoric people noticed that a damp skin decayed, and a dry skin became hard and horny, but a dry skin which lay in contact with its own fat remained pliable. The practice of rubbing fats and oils into skins has been little changed in the modern treatment of the finest furs and chamois skins.

Another ancient method of preserving skins was by smoking them over a wood fire. This method of curing skins was quicker than oiling them and it gave a fairly satisfactory product.

As early as the Smooth Stone Age in Egypt and Asia Minor, the people of these countries had learned how to tan leather. The process used in these ancient times differed but little in principle from that of to-day. Oak bark, chestnut bark, gall nuts, or sumac branches were soaked in water until fermentation took place. When skins were soaked in this plant concoction, they became soft and pliable, and would not decay.

The process of tanning was more than likely stumbled upon when some person of prehistoric times was attempting to dye a piece of leather. The chief dyes of ancient times were plant extracts, made by placing roots, or stems, or fruits of plants in water and leaving them there until fermentation took place. A liquor of this sort would frequently dye a piece of cloth a color that proved to be both attractive and lasting. An attempt to dye a skin in the same way would have resulted in producing a leather of a very desirable quality, even though it might not have given the same color that this pioneering experimenter had in mind.

The ancients did not know what process actually took place during the tanning of leather. We now know that the fermentation of the vegetable product used results in the formation of a group of substances which we call "tannins." These tannins react chemically with skins to produce a soft and durable leather. The tannins are named after the tanning process. The origin of the word *tanning* is somewhat uncertain, but it is thought that it came from the same ancient word as *tawny*, and that it referred originally to the color of the skins that were produced by this process. The ancients tanned leather to make sandals, belts, garments, bottles, shields, and parts of furniture.

MILK AND BUTTER

Milk was the third product of importance that was obtained from the cow. The use of this product dates from the domestication of these animals. Hand in hand with the introduction of the use of milk came that of the two most important dairy products, butter and cheese. In Abraham's time, milk and butter were common articles of diet. This patriarch's hospitality to guests is described in Genesis 18:8, as follows: "And he took butter, and milk, and the calf, which he had dressed, and set it before them." Solomon, in Proverbs 30:33, says, "Surely churning brings forth butter."

CHEESE AND SOAP

Cheese also is mentioned in the Old Testament. In I Samuel 17:17, 18, a description is given of how Jesse sent his son David to carry food to his three brothers, who were fighting in Saul's army against the Philistines. Before sending the lad on his way, Jesse said to him: "Take now for thy brethren an ephah [about a bushel] of this parched corn, and these ten loaves, and run to the camp of thy brethren; and carry these ten cheeses to the captain of their thousand, and look how thy brethren fare."

The product which man began to obtain from cattle next after meat, leather, milk, butter, and cheese, was soap. Perhaps many of us have seen soap made at home by boiling the fatty refuse of the kitchen with lye. These two substances combine chemically as follows:

Stearin or Beef Tallow	+	Sodium Hydroxide or Lye	=	Sodium Stearate or Soap	+ Glycerine.

Other fats such as palm oil, coconut oil, olive oil, or various animal fats may be used in soap-making. Beef tallow, however, is the one most extensively used.

The ancients did not know the art of soap-making. They used a kind of lye, obtained from pouring water on wood ashes, as an aid in washing their clothing. The glue-like sap of a species of soapwort also was used as a laundering agent. It was not until about the first century A.D. that soap was discovered. Its first use was as a pomade for the hair. About a century later soap came into use for washing the body. Until the Middle Ages it was used only for toilet purposes or for laundering the finest of articles. Lye obtained from wood ashes was still used for washing ordinary garments.

At the time when our own country was founded, little increase had been made over ancient times in the number of articles of everyday use that were obtained from cattle. Meat

was butchered by each family or, in a few cases, by a local butcher who sold his products to the inhabitants of his own community. Milk was obtained from the family cow, and butter and cheese were made at home. Soap-making was a household art. Candles, a product made from beef tallow, were also a homemade article. Leather-tanning only was a trade, as it had been ever since the earliest times. The first tanner, according to historical records, came to these shores as early as 1623. This was Experience Miller, who came to Plymouth at that time on the good ship *Ann*. Until 1628 the only shoes worn by the settlers of the Plymouth colony were those sent from England. The settlers also wore mocassins which the Indians had taught them how to make. In that year Thomas Beard and Isaak Hickman came over from England to make shoes for the colonists. They brought with them "divers hydes both for sole and upp leathers" which they intended to convert into boots and shoes.

ADVENT OF THE PACKING HOUSE

After the middle of the nineteenth century the important products obtained from cattle became more and more numerous. The invention of refrigeration devices was the chief factor responsible for this change. When it became possible to butcher meat in one place and ship it to people living thousands of miles away, the local butcher gradually became less common.

When the packing-house industry had become established, many parts of the animal which had formerly been thrown away were saved and made into useful products. Chemistry is the science that is responsible in large measure for the high development of the packing-house industry. Each plant maintains its own chemical laboratory, and it is the business of the chemists employed there to find out how to save and make use of every part of all animals slaughtered.

THE TRAVELING STEER

"Once there was a steer," reads an advertisement of a well-known packing company, "that went all over the world. But not until after the meat was prepared for market."

The fine hairs in its ears went to Paris to be used in artist's "camel's hair" brushes.

The shin bones went to Sheffield, England, where they became knife handles that were carried in men's pockets to South Africa and London.

The sinews and tendons went to Canada and Mexico—first boiled down into glue used in the manufacture of furniture.

Every part of this steer went somewhere and was used—even tiny glands no bigger than peas went to pharmaceutical houses to be made into medicine.

This advertisement in reality does not do justice to the wanderings of the parts of the packing-house steer.

A 1,000-pound steer slaughtered in a modern meat-packing plant yields about 550 pounds of dressed meat. Scarcely an ounce of the remaining 450 pounds goes to waste, however, because scientists have devoted themselves to a painstaking study of possible by-products. As a result of their work, every part of the animal from the hoofs to the horns is put to some important use. There are 400 important products now put out by packing houses. The following list, quoted from a publication issued by one of the packing-house concerns, includes the outstanding products derived from cattle:

Edible Fresh Beef Products

Loins	Chucks	Necks	Ribs
Tenderloins	Backs	Brains	Plates
Short ribs	Milts	Livers	Hanging tenders
Sweetbreads	Oleo	Gelatine	Tongues
Tripe	Ox lips	Hearts	Skirts
Regular rolls	Clods	Ox-tails	Kidneys
Rounds	Flanks	Stearine	Suet

Inedible Beef Products

Hair	Neat's-foot oil	Meat meal
Hide	Hoof meal	Tallow
Glue	Bone	Lubricating oil
Horns	Bone meal	Soap
	Bone black	

Pharmaceutical or Medicinal Products

Rennet (calf)	Peptone powder	Pituitary powder, tablets, liquid
Thyroids	Extract of red bone marrow	Thromboplastin solution
Suprarenals	Corpus luteum	Kephalin
Pineal gland	Thymus substance (calf)	
Ox-gall		

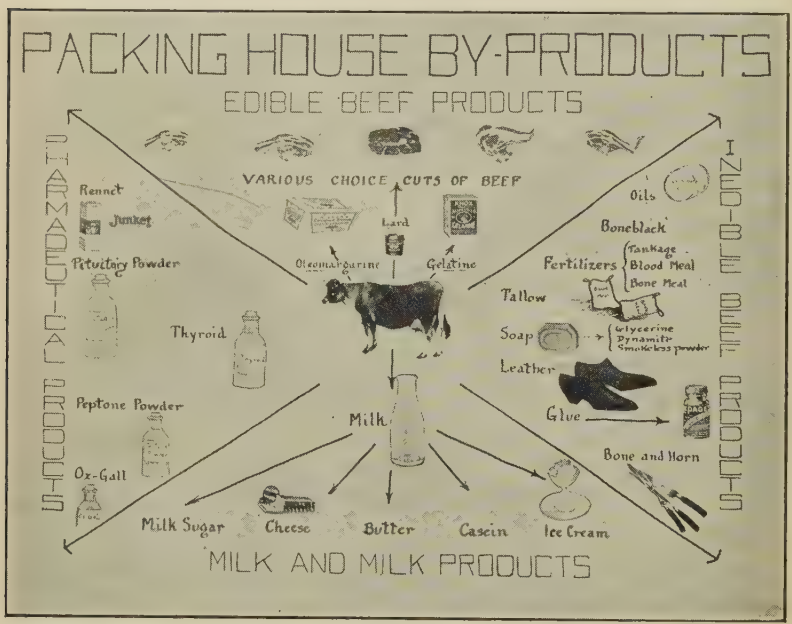
Besides the edible beef products derived from a slaughtered animal, many inedible products of great importance are obtained. The hide is removed and converted into leather. The hair, which is removed from the hide previous to the tanning process, is not thrown away, because some builders find that it is valuable as an ingredient of plaster. Cheap felts and stuffings are also made from the hair.

Fat trimmings, which are removed from the edible portions of meat, have many uses. Chief among these is in soap-making. Whereas our colonial grandmothers made all of their own soap in kettles over the kitchen fire, most of the soap used to-day is made in factory kettles the size of five-story buildings. The glycerine formed as a by-product of soap-making is not thrown away nowadays, although it was discarded for years before its value was known. Instead, it is used to make nitroglycerine, dynamite, and smokeless powder.

Scrap fat from packing houses has uses other than soap-making. Tallow candles are made from beef tallow. Bone fat, obtained by steaming all bones except those of the feet, may be used for soap or candle-making. One of the chief constituents of oleomargarine is obtained from the ruffled fat taken from around the digestive organs of cattle. Neat's-foot

oil is a valuable oil obtained by boiling the bones of the feet in water. This oil makes an excellent lubricant for delicate machinery such as clocks, guns, and sewing machines.

Bone from which the fat has been removed may be heated until it is charred. This leaves an excellent type of charcoal called bone black or animal charcoal. Bone black has the vir-



THE COW—NOW

This speaks for itself. Six thousand years from now a larger page will be needed for this illustration.

tue of absorbing coloring matter from solutions with which it comes in contact. For this reason it is used in the purification of sugar. It may also be used to remove colors and odors from drinking water. Bone black also serves as a pigment in stove polishes and black paints.

Scrap bone from the packing house may be ground and used as fertilizer under the name "bone meal." Dried blood forms what is known as blood meal, and it is also used as

fertilizer. Scraps of meat which can be used for no other purpose are ground into meat meal and sold as chicken meal.

Gelatin and glue are likewise important packing-house by-products. Gelatin is made either from the clean, dry bones carefully selected from the feet and heads of cattle, or from the hides of calves. Glue, made from the same raw materials as gelatin, requires less special care because it is not a food product.

Many articles are made from bone and horn. Handles for knives and razors, pipe stems, dice, chessmen, buttons, washers, rings for teething babies, combs, hairpins, and umbrella handles are made from the leg bones and the horns of packing-house cattle.

MEDICINAL STUFF FROM GLANDS

Among the most valuable of the beef by-products is a group of pharmaceutical or medicinal preparations. These products are prepared from the glands of the slaughtered animals. This use of glandular preparations is one which has been carried on only in recent years. It has resulted from the discovery that many human disorders result from the improper functioning of certain glands of the body.

The activity of a number of the glands in the human body has been known for some time. For example, it has been known that the glands of the mouth, stomach, and other parts of the digestive tract secrete solutions which bring about the digestion of foods. If these glands fail in their work, it is possible to give some relief by administering the extract of a similar gland from a cow or sheep. There is, however, a type of gland in the body which does not secrete a fluid which pours into the digestive tract and aids directly in the digestion of foods. These are the so-called ductless glands. The nature of the ductless glands is just beginning to be understood by physiologists. It has been discovered that they are really chemical factories which manufacture hormones or agitators. These

are carried by the blood to all parts of the body. These hormones regulate such bodily processes as growth, the laying on of fat, the proper functioning of the brain, and the production of bodily energy. If one of these glands fails in its duty, the person will fail to grow up, or will grow very slowly; if another fails, the person may become too lean or fat; the improper functioning of another gland may result in insanity or other mental trouble; when another fails, the person may be unable to get enough bodily energy from the food he eats.

Among the ductless glands, the duties of which are beginning to be understood, is the pituitary gland. This gland is so important that nature has placed it in the center of the brain and protected it with a special bony encasement. Another gland likewise situated in the brain is the pineal gland. Two other glands, the thymus and the thyroid, are found in the neck. All of these glands have something to do with keeping the mind and the body in working order. A pair of glands, the suprarenals, are located in the fatty tissues above the kidneys. These produce a substance called adrenalin, which assists in controlling the heartbeat and the size of the blood vessels. When a person is angry or frightened, these glands secrete larger amounts than normally. Because of the resulting increased blood pressure, a person can actually fight harder when angry, or run faster when frightened.

Lately the pancreas has been included in the list of ductless glands. Although it has a duct through which a juice that aids in the digestion of foods is poured into the intestines, it also secretes a substance called insulin, which enters the blood and regulates the production of bodily energy from sugar. When the pancreas fails to produce enough insulin, the disease known as diabetes results. The insulin treatment for diabetes has proven to be the most effective introduced so far.

In spite of the fact that extracts from the digestive glands of sheep and cows have long been used as medicine for digestive troubles of humans, it has been discovered only recently

that extracts from the ductless glands of these same animals will remedy diseases caused by faulty functioning of the same glands in human beings. The preparation of these extracts has become a commercial enterprise, as is shown by the list of medicinal products of this kind listed on page 459. In some cases, the production of large quantities of extract is not extremely difficult. In others, however, the glands of a great number of animals must be used to produce very small amounts of the active substance. The pineal glands of 15,000 cattle, for example, are required to produce a pound of pineal extract.

CANNED MILK AND SYNTHETIC GEMS

In the same way that the invention of refrigeration took the butchering industry to the packing house, this invention has also made the commercial dairy the center of the milk industry. With the coming of dairies, the number of milk products has grown from three or four to three or four dozen. Milk, cream, butter, and cheese are produced in larger amounts than formerly. In addition to these, many other by-products are produced which could not be made when milk-products were produced only at home.

Concentrated milk is now on the market. Milk may be boiled down or entirely evaporated, so that the nutritive ingredients occupy a smaller volume than whole milk. Products of this sort are either canned or sealed in bottles. In this form milk may be kept for long periods of time, or carried on excursions and expeditions where the transporting of whole milk would not be practicable.

The ice-cream business would result in waste of a large part of the milk used if the chemist had not again come to the rescue. The skimmed milk, from which the cream had been removed by a separator, was at first either returned to the farmers for pig-feed or was thrown away. The chemist showed how this could be used as a source of many products, chief of

THE OLD-FASHIONED DAIRY-MAID IS NOW ALMOST COMPLETELY SUPPLANTED BY THE MODERN DAIRY

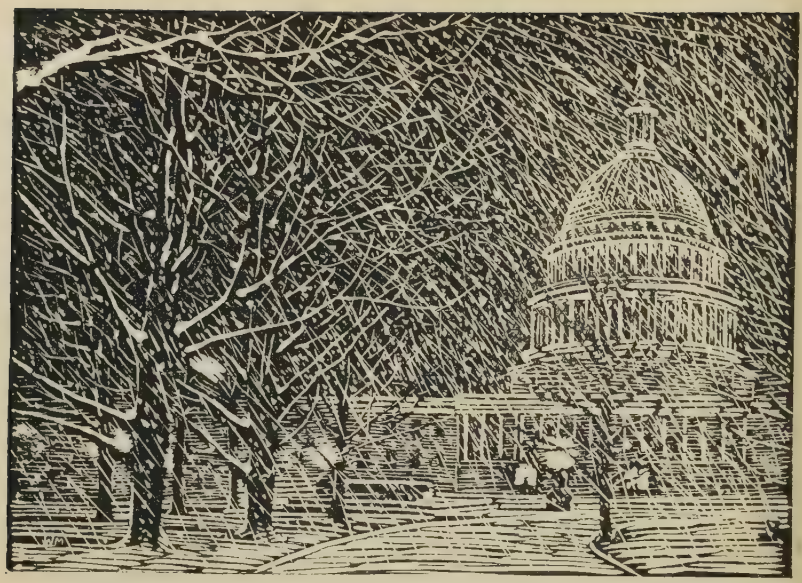
which were casein and milk sugar. After this was discovered, plants were erected for the recovery of these products, and the ice-cream manufacturer found a ready market for skimmed milk.

Casein is a white curd which forms in milk when it becomes

sour. Its formation may be hastened by adding a few drops of acid or a junket tablet to the milk. When casein is treated with lime or ammonia water, it forms a preparation which may be used for the stiffening of silks in the textile industries. Casein preparations are also used for fastening sheets of paper together in the making of cardboard. Other casein products are used as a sizing material in the making of paper and as an adhesive for sticking thin layers of coloring matter to paper. Casein is sometimes added to whitewash to give it better sticking qualities. It is used in various paints such as casein enamel paints and kalsomine washes. It is also used in sprays for fruits and vegetables. In addition to its use in kalsomines and adhesives, casein has found an important application in the making of beads, synthetic gems, and other plastics.

After the casein is removed from skimmed milk, the remaining whey still contains lactose or milk sugar, a product quite similar in composition to cane sugar. This may be removed, and it forms an important ingredient of prepared baby foods.

The cow, an animal of importance from the earliest times, is more important than ever in this day and age, since the chemist has discovered how to make use of the many packing-house and dairy products once wasted. The development of by-products has resulted in making it possible to buy dressed beef at a lower price per pound than the animal costs on the hoof. The story of what a chemist can do with a cow shows better than almost any other chapter in the history of humankind to what a great number of uses inventive man can put the materials that nature has to offer.



THE CAPITOL OF A NATION DESTINED TO BE A LEADER IN MAKING SYNTHETIC PRODUCTS

Incidentally, this illustration is a woodcut, and wood, together with its relatives—cotton, cornstalks, and cane—will provide much of the raw material for making new products not yet discovered.

CHAPTER XXV

SYNTHETIC STUFF

Intelligence . . . is the faculty of manufacturing artificial objects.
—Henri Bergson

MAN reaches a high plane of culture indeed when he learns how to create entirely new products out of raw materials that do not bear the slightest resemblance to the new materials. It is one thing to find out how to improve products found in nature so as to make them better able to serve the purpose for which they are intended. It is quite another to find out how to produce an entirely new material which has no counterpart in nature at all. Rayon and the synthetic dyes are splendid examples of stuff created by man out of homely substances. Other synthetic products are equally important and filled with romance.

CALCIUM CARBIDE

There is no synthetic substance of more interesting history or more important application than calcium carbide, the material which yields acetylene when water is placed on it.

The discovery of the first practical method of making calcium carbide commercially was made in May, 1892, at a plant in Spray, North Carolina, owned and operated by Major James Turner Morehead. The discovery is attributed to Thomas L. Willson, a Canadian electrical engineer, whom Morehead had employed to look after the details of installing and operating an electric furnace in which he hoped to make metallic aluminum and to carry out other metallurgical operations.

EDMUND DAVY DISCOVERS ACETYLENE

The discovery made at the Morehead plant gave the world the first means of making acetylene commercially, although the gas had been known as a scientific curiosity for more than half a century previous to 1892. Its first discovery was made in 1836 by Edmund Davy, a cousin of Sir Humphry Davy who started his scientific career as the latter's assistant. Davy made this discovery by placing water on potassium carbide. The potassium carbide that he used was likewise the result of an accident which occurred while he was trying to produce metallic potassium by heating a compound of potassium with charcoal at a high temperature.

Edmund Davy communicated his discovery in March, 1836, to the British Association for the Advancement of Science, and applied the name *bicarburet of hydrogen* to the compound that he described.

The name *acetylene* was applied to Davy's bicarburet of hydrogen in 1860 by Berthelot, the French chemist, who determined the composition of the gas by careful analysis, and named it because of its relation to other previously know-

chemical compounds. Berthelot published a series of papers from 1860 to 1862 in which he described with scientific exactness the characteristics of this gas, and suggested various methods of preparing it.

WOEHLER AND CALCIUM CARBIDE

The year in which the last of Berthelot's papers were published, Woehler, a great German scientist, succeeded in making calcium carbide, a compound of calcium and carbon, and in decomposing this compound with water. The gas formed during Woehler's experiment was the same material produced by Edmund Davy, namely, acetylene.

The importance of Woehler's experiment lay in the fact that calcium carbide is made from two substances that are comparatively cheap, namely, lime and coke. The method which Woehler used, however, was so laborious that the cost of producing acetylene would have been prohibitive. Before the Willson-Morehead discoveries, therefore, acetylene was so rare that only half a dozen scientists had ever seen the acetylene flame, and few knew about the wonderful heating and lighting possibilities of this gas.

THE ELECTRIC FURNACE

One of the most important factors leading to the preparation of calcium carbide by a cheap process was the electric furnace. Soon after the discovery of this device, Major Morehead installed a crude electric furnace in his workshop for the purpose of investigating its metallurgical possibilities. Morehead was a Southerner who had lost practically all his wealth in an effort to rehabilitate his state in the reconstruction period following the Civil War. Previous to this time he had owned a cotton mill, a woolen mill, a waterpower plant, a grist mill, and a general store; these he had sold one at a

time to pay his debts. He was left with but one asset—the water rights to a small section of a minor stream near Spray on which his previous mills had been located. On this right he built a small shack and began his experimental work with the electric furnace. He later extended his work to such an extent that it seemed advisable to borrow money and employ helpers.

Among his first helpers was his son, John Motley Morehead, who was at that time a student in chemistry at the University of North Carolina, and who was accustomed to help with his father's work during vacations. Somewhat later, Major Morehead employed Willson to act as his electrician, and together they formed a company called the Willson Aluminum Company. At the time of the formation of this company, three other men were employed as helpers. They were E. F. Price, Jesse King, and John Motley Morehead (Major Morehead's son, who had previously worked only at odd times). The exact circumstances surrounding the accidental discovery of calcium carbide are described in the minutes for 1923 of the International Acetylene Association as follows:

> Mr. Willson was nominally at the head of the company, and he, together with the other three mentioned, conducted various experiments; Mr. Willson having primarily in mind the making of aluminum, Major Morehead not only aluminum, but also other products which might be fused by the intense heat of the electric arc. The Company was handicapped by lack of funds necessary to carry on their experiments, and Willson, as an electrician, undertook to design his own dynamo. It is unfortunate that this dynamo has long since gone to the scrap heap. . . .
>
> It was about this time that Hall invented a process for making aluminum, using the electrolytic cell. Mr. Willson thought that he could accomplish the same thing through the excessive heat of the electric arc, making the electric furnace produce aluminum somewhat in the same way that the blast furnace produces iron. His first experiments consisted in introducing alumina and coke into the furnace. These proved a failure. Then he attempted to produce aluminum bronze by adding metallic copper to the mixture.

In this he was successful, but the costs were prohibitive, and the percentage of combined aluminum was small.

As a result of these various experiments and failures, Mr. Willson, as well as the other three men who were associated with him, became discouraged, the company had practically exhausted its resources, and the morale was at a low ebb. Mr. Willson would lay out work for his associates, which may or may not have been carried out, as he had become discouraged and did not follow the work closely. In their discussions, some one conceived the thought that results might be achieved if they first produced metallic calcium, a thought which to-day would seem absurd, since metallic calcium is more difficult to obtain than metallic aluminum. In any event, an experiment was conducted in which coal tar and lime were used without any regard for theoretical proportion, with the result that fortunately the proportions happened to be such that a metallic-like product was produced, which they thought was metallic calcium.

At the time this experiment was conducted, Mr. Willson was in Asheville, North Carolina, and the experiment was conducted by his three associates. It was customary in all of the tests to take a sample of the material from the furnace when in a molten or semi-molten condition, and cool it in a pail of water for laboratory tests as to quality. This was done in this instance, and the material at once gave off a gas, which was thought to be hydrogen, as that would have been the gas to expect from metallic calcium brought in contact with water. After noting the results of the first sample, a larger sample was tested in more water to see if it would burn.

Messrs. Price, Morehead, and King proceeded to light it, and with uncanny foresight, as you will note, precaution was taken. Mr. Morehead took a long fishing pole, on the end of which Mr. Price dropped a piece of waste; Mr. King lit the waste, Mr. Price dropped a piece of the unknown substance into a pail of water, Mr. Morehead swinging the burning waste over the pail, all three standing at a safe distance away. The result was that the gas ignited at once with a puff, giving off a heavy smoke.

These three men at once began to theorize as to the nature of the gas, Mr. Morehead arguing that it could not be hydrogen gas, since such gas contained no carbon and hence could create no smoke. When Mr. Willson's attention was later called to the flame, he insisted that the product was metallic calcium, and that the gas was hydrogen. The other three men held to their conviction that it was not hydrogen, but they did not know what the gas was.

As a result of their argument, a sample of the product was forwarded to the University of North Carolina, and Dr. Venable of that University, assisted by one of his post-graduate students, William R. Keenan, Jr., also a native of North Carolina, analyzed the gas and pronounced it "acetylene" and the furnace product "calcium carbide."

The date of the electric furnace experiment referred to above was May 2, 1892.

Among other scientists to whom Willson forwarded samples of the newly discovered electric furnace product was Lord Kelvin, the famous English physicist and chemist. Lord Kelvin's reply to Willson, dated October 3, 1892, stated that the substance received had been analyzed by him and had proved to be calcium carbide.

In this discovery, as in many others, the process was discovered independently by two experimenters. Henri Moissan, a French scientist, was trying in the same year to reduce metallic oxides in a furnace lined with lime, when he also prepared a small bit of calcium carbide. This discovery was also an accident, since Moissan had not anticipated that the carbon of his electrodes would combine in that way with the calcium in the lining of his furnace.

Moissan mentioned his discovery in two lines in a paper which he published in December, 1892, but he considered the matter of no practical importance at the time. Later, when the commercial aspects of the calcium carbide discovery, as made by Morehead and Willson, became more generally known in Europe, friends of Moissan claimed that he had been the first to discover the commercial method of making this compound. In view of the fact that correspondence relating to the discovery in Spray, North Carolina, particularly that between Willson and Lord Kelvin, was dated before the first small mention of the making of calcium carbide by Moissan, the priority of the American product has long since been generally recognized, except in France.

BICYCLE LAMPS AND BLINKERS

One of the first uses of calcium carbide was to generate acetylene in bicycle lamps. The miner's carbide lamp for use in non-gaseous mines was the outgrowth of this. It was said to have been designed following the practice of a few miners, who rode bicycles to work, of detaching their bicycle lamps and taking them with them into the mines. Acetylene blinkers are now familiar in every small town and along every roadway.

Aviation routes may now be lighted with fog-piercing acetylene lights which burn acetylene stored in some porous material in steel tanks.

In marine lighting, acetylene has made the automatic lighthouse a possibility. The lighthouses in which, a generation ago, Grace Darling, Ida Lewis, and Rebecca and Abigail Bates lived with their fathers and helped to rescue wrecked sailormen have been abandoned in favor of smaller structures, automatic in every detail.

The new automatic acetylene marine light turns itself on at dusk and off at sunrise by the use of a special selenium cell which operates the valves and is sensitive to light. It flashes automatically, thus cutting down the quantity of gas consumed and making it more visible as well. It even changes its own mantles. Only once in every few months does it require the ministration of a human hand, and this is to remove the empty tanks of acetone acetylene solution and replace them with specially charged ones. Most of the automatic parts of this wonderful light were the inventions of Nils Dahlen, a Swedish scientist of exceptional ability.

Acetylene is used for many things besides lighting. It serves as a fuel for the rural housewife's stove, hotplate, iron, and water heater, and it makes the oxyacetylene blowpipe possible. This latter device consumes a greater quantity of acetylene than anything else.

The oxyacetylene blowpipe is indispensable in the fabrication and maintenance of plant machinery of every description. It helps to build the intricate equipment of the textile mill and to keep it going; it keeps paper mills in active service; it renews mine machinery; it helps to construct and maintain elaborate equipment in all sorts of chemical industries such as tanneries, sugar mills, oil refineries, and canneries; it joins together sections of pipe for conveying oil or gas for distances of hundreds of miles; it is effective alike in making jointless steel smokestacks and all-welded seamless water coolers; it welds the covers of kitchen pans and the snouts of tea and coffee pots; it fashions metal beds; it constructs shoe dies, and then refabricates them when shoe styles change; it makes seamless bracelets and rings, and fancy articles of jewelry; and it helps in the building of bridges.

The oxyacetylene blowpipe makes reclamation welding a possibility. In the cast-metal industry, imperfect castings once rejected and sent back to the furnace now have their defects corrected by welding, thus effecting a material saving in cost of production. A crack in a bell may now be welded, and the tone left unimpaired. Broken parts of the auto, of the airplane, and of railroad equipment, once requiring weeks to mend, are now made as good as new in only a few hours. Machinery parts once thrown away are now reclaimed by oxyacetylene welding, so that it is hard to know now when a scrap pile is really a scrap pile.

HARD STUFF

Abrasives have had an important part to play in the advance of civilization from the very earliest times. When man passed from the wood through the various stone ages, his progress was dependent to no small extent upon the materials he could find to assist him in fashioning the various articles that he used as tools, utensils, and weapons. Flint was used in very

early times; and emery, or impure aluminum oxide was used for polishing in the time of the Pharaohs.

Modern chemistry has revolutionized the art of shaping things. Synthetic abrasives have been developed which make it possible to remodel the shape of anything from a human tooth to a diamond.

CARBORUNDUM

The discovery of the most important modern synthetic abrasives was made possible only with the invention of the electric furnace. This abrasive is a compound of carbon and silicon made by heating together coke and sand at high temperatures. It was invented by Edward Goodrich Acheson about 1880 in a little shop in Monongahela, Pennsylvania. The following was written by Acheson shortly after his product had been definitely placed on the market:

> The value of a good abrasive was brought to my attention in 1880 by Dr. George F. Kunz, of Tiffany and Co., New York. I also remembered the observation of clay impregnated with carbon I made . . . and decided to make experiments on impregnating clay with carbon under the influence of electric heat. An iron bowl such as plumbers use for holding their melted solder was attached to one lead from a dynamo and filled with a mixture of clay and powdered coke. The end of an arc-light carbon attached to the other lead was inserted into the mixture. The percentage of coke was high enough to carry a current, and a good strong one was passed through the mixture between the lamp carbon and the bowl, until the clay in the center was melted and heated to a very high temperature. When cold, the mass was examined. It did not fulfill any expectations, but I, by chance, happened to notice a few bright specks on the end of the arc carbon that had been in the mixture.
>
> I placed one on the end of a lead pencil and drew it across a pane of glass. It cut the glass like a diamond. I repeated the experiment and collected enough of the material to test its abrasive qualities. I mounted an iron disc in a lathe, and, oiling its surface,

applied the material which adhered, and with this revolving disc I cut the polished face off the diamond in a finger ring still owned and worn by me. I now made a small furnace of bricks, and after much patient work, had what I considered enough to take to the lapidaries in New York City. A friend by the name of Wm. C. McAllister—a druggist of Monongahela—and I started for New York City. On the way we coined a name for my new, and as yet, unnamed material. Under the impression, without any chemical analysis, that it was composed of carbon and corundum, I called it Carborundum.

I had a diamond-cutter on John Street use some of my product to repolish the diamond I had ground, and the remainder he bought from me at 40 cents per carat, or approximately $800 a pound, and with the proceeds I purchased a microscope to help me in studying the structure of carborundum. A great deal of time and energy were expended in an effort to develop a trade with the lapidaries, but the consumption of abrasives in this line was small, and mainly covered by the refuse matter from diamond cuttings and chippings.

I gradually increased the size of my furnace and sent samples to various emery-wheel manufacturers to be made into small wheels. Without exception, these companies reported that it was not possible to make the material up into successful wheels. Not discouraged, I undertook experiments in these lines. I organized the Carborundum Company, and incorporated it for $150,000 on September 21, 1891. One-third of the stock was issued to the stockholders of the Monongahela Electric Light Co., for services the Carborundum Co. had received from the Light Company. A new field opened up at this time for carborundum.

Mr. George Westinghouse had secured the contract for lighting the Columbian Exposition buildings in Chicago. The Exposition was to be held in 1893. The Edison Electric Light interest secured an injunction, restraining Westinghouse from making a lamp of one piece of glass; Westinghouse devised a lamp made of two pieces, fitted together with a ground joint as a stopper fits into a bottle. He found small carborundum wheels to be the most efficient means for grinding the joint between these two pieces. I made with my own hands some 60,000 small wheels for this work and received from the Westinghouse Electric and Manufacturing Company over $7,000 for them. With this money the Carborundum Company bought its first dynamo; its electric current up to that

time having been furnished by the dynamos of the Monongahela Electric Light Company.

I think it was in 1893, January, I sent out 12,000 lithographed cards to that number of dentists. In one corner I punched a hole one-half inch in diameter, and in it I placed a carborundum wheel of that diameter and $\frac{1}{16}$ inch thick. The cards being made of soft heavy paper, the wheels were held firmly. On one side of the card were lithographed the words: "The compliments of the season and a carborundum wheel. Try me wet or dry!" On the reverse side was a price list.

By return mail I received sufficient orders and money to pay for the cards, wheels, and postage. These wheels had been made by myself. I had two small kilns built, and went earnestly to work to make a high-grade vitrified wheel. The success of these wheels caused Mr. Lee S. Smith of Pittsburgh, who was in the dental supply business and whom I had formerly endeavored to interest in carborundum dental goods, to wish to take the sole agency for the product. He placed an order for $5,000 worth of wheels and points, and with this money, the Carborundum Company made an exhibit at the Chicago Exposition, and much attention was attracted to the material. As a result of this exhibit, I sold, before the year 1893 through a Mr. Wissenburger, to an Austrian Bank (known as the Lander Bank of Vienna) my patents for Austria Hungary, receiving for the sale $20,000.

I should have stated earlier that some months after the discovery of Carborundum, I learned from analyses I had made that it was a compound of carbon and silica, and not alumina, the formula being SiC. On January 1, 1910, the company was using 10,000 electrical horsepower, and was producing carborundum at the rate of ten million pounds per year, the capital of the company having increased to $600,000.

In 1895, I secured a U. S. patent for purifying carbon. In 1896 I obtained a U. S. patent for the manufacture of graphite. On January 17, 1899, I secured still another one in this series, i.e., on the manufacture of graphite articles.

CELLULOSE MIRACLES

Among the many triumphs of modern synthetic chemistry, none is more remarkable than the products that the

chemist has obtained from cellulose. Cellulose from wood, cotton, linen, straw, cornstalks, or cane consists essentially of a compound to which there has been assigned the general formula $(C_6H_{10}O_5)_x$.

Paper, cardboard, rayon, Cellophane, artificial sausage-coverings, celluloid, imitation ivory, Duco, imitation pearls, and films, are representative of the many articles made from this main product of vegetable life—cellulose.

Cellulose is synthesized from its elements in nature's own laboratory. Carbon dioxide and moisture are built up into this complex compound through the agency of light. We, in turn, take the cellulose built up in nature and convert it into numberless compounds used to make articles for our daily needs.

This poetical squib on cellulose tells of its versatility:

There is a stuff called cellulose
  That has uses a plenty.
These uses number mighty close
  To one hundred times twenty.

They take CO_2 from the air
  And hook up water to it.
You couldn't do it if you'd care
  To try and try to do it.

And then we take this cellulose,
  Change it in every feature,
Make boxes, paper, films, and clothes
  To deck the human creature.

PAPER, FIBERS, AND FILMS

Paper-making is one of the oldest of the cellulose manufacturing processes. It now ranks ninth among the industries of the United States. In 1899 the Fourdrinier machine was invented, in which digested cellulose went in at one end, and

finished paper ready for market came out of the other. In making paper, raw cellulose is digested by means of chemicals into a pulp of independent fibers. The fibers are in turn matted together again into a smooth sheet.

Photograph by Brown Bros., N. Y.

PRODUCTS OF THE RESEARCH LABORATORY

Bakelite, a newly discovered substance, is used for such a variety of products as the telephone set, molded insulators, dental chair arm, automobile distributor head, ammeter frame, and a case for the standard voltage reference cell.

If cellulose is digested to independent fibers, as in paper-making, it may be further treated chemically so as to render it soluble in various reagents. It may then be dissolved and spun through tiny orifices into a bath in which it is insoluble. It thus solidifies into tiny filaments, suitable, after purification, for making beautiful fabrics. The rayons and other synthetic fibers are made in this way.

If dissolved cellulose is forced under pressure through a

manifold or slit-like aperture into a hardening bath, it solidifies in thin sheets. An exceptionally thin sheet made in this way is called Cellophane by its manufacturers, the Du Pont Cellophane Company. Cellophane can be made in a variety of thicknesses, colors, or embossed designs. It is waterproof, dustproof, and germproof, and is setting new standards in the art of wrapping merchandise.

A solution of cellulose in certain solvents can be made to harden in films suitable for photographic purposes. If these are coated with a mixture of gelatin and a light-sensitive substance such as silver bromide, they serve to record the features of the whole family, from grandfather to the pet dog, as well as the actions of the newest addition to the family from two weeks old on.

CELLULOSE LACQUERS

If cellulose or compounds of cellulose are dissolved in suitable organic liquids, a quick-drying lacquer is produced which has revolutionized modern painting. Particularly has the importance of these products been felt in the automobile industry.

Five years ago the paint shop was the neck in the bottle in every automobile factory. Cars by the thousands were being assembled, only to be held up from ten to thirty days while paint was applied, coat upon coat. The final coat was baked on to shine for a few months. Black was the only color giving anything like good results.

Now cars can be sprayed with beautifully colored cellulose lacquers in a very short time. The finish is also very much more lasting than the old-fashioned, tediously applied paints. In addition to cars, everything from bird cages to locomotives are being lacquered with the same type of product, and brushing lacquers sold in small cans for home use can be applied for the rejuvenation of old furniture.

MY LADY'S COMB AND BRUSH

Cellulose solutions can be spun into textile fibers, forced into thin films, painted on auto bodies and other surfaces, mixed with shiny material of fish scales and made into "pearl" beads, and hardened into a tubular shape and used as sausage jackets.

What could be more versatile?

It can also be molded into combs, brushbacks, mirrorbacks, shoehorns, powderboxes, and a thousand and one other articles of everyday use.

BAKELITE

Bakelite is another synthetic article that can be molded into an almost unlimited number of useful articles. This so-called resinoid is made from phenol, or carbolic acid, and formaldehyde.

Phenol is a product derived from coal tar and familiar to most of us because of its antiseptic qualities.

Formaldehyde is a gas, soluble in water with the formation of a solution called formalin. It is used to preserve zoölogical specimens, and its pungency will always be remembered by any one who inhales any of its vapors.

How two such unlikely substances can unite to form the resinous product used for making beads, telephone transmitters, and cigarette holders is a mystery to every one, even to the chemist.

Bakelite was discovered in America in 1907 by Dr. L. H. Baekeland, who had come to this country from Belgium a few years previously. Baekeland had previously invented some superior photographic papers. He has come to be numbered among the great chemists of modern times because of his work with synthetic resinoids.

Bakelite finds one of its chief uses as an insulating material. It serves as radio panels, battleship insulators, barriers be-

tween circuit breakers, conduits and bushings through walls and floors, instrument panels, and insulation on telephone switchboards.

Bakelite is also used to make airplane propellers, pipestems, gift novelties, billiard balls, grinding wheels, telephone mouthpieces, ash trays, and bead necklaces. It has been suggested as an excellent material for making furniture when the raw materials become sufficiently cheap to warrant it. Perhaps our descendants of a few generations hence may never see any wooden chairs or tables except in museums.

CHAPTER XXVI

WASTE STUFF

Riches may be well compared unto cisternes or pooles which a small stream will easily fill, if there be no leaks or wasts; but small wasts and expenses continuing, and not prevented, have deceived and undone many.

—Higford, 1650

As the number of people inhabiting the earth continues to increase, the necessity for utilizing every available particle of stuff becomes more and more urgent. Some parts of the world have been crowded for quite a time, and in most cases these have led the rest of the globe in obtaining valuable products from waste materials.

Take the subject of coal, for example. Some nations are quite short in their coal supply. These are the peoples who have been the first to find out that a lump of soft coal is something to be cherished as more than a mere chunk of fuel. Through a long series of developments they have demonstrated many things.

First of all, they have shown that wasted bits of coal can be cemented together into briquets which serve as an excellent fuel. There are many people in the world who have scarcely ever seen any sort of fuel except briquets made from coal waste.

Then, too, they have shown that soft coal when heated out of the air will give off quantities of gas, leaving coke as a residue. The gas can be used as an industrial and commercial fuel more convenient for many purposes than the coal itself. The remaining coke is also just as good a fuel as the same weight of undistilled soft coal would be.

The habit of coking coal for the gas and coke was practiced for years before the value of coal tar was discovered. The

romantic history of coal tar, well known to all of us, stimulated scientists everywhere deliberately to search for hidden treasures in other waste products.

Cellulose threatens to rival coal tar in the number of products which it can be made to yield. Cotton is an interesting example. For centuries it was used solely as a source of cotton fibers. The seeds were removed by laborious methods and were thrown away.

Now, for every 1,000 pounds of cotton fibers that find their way into our bed sheets and other types of cotton textile fabrics, 2,000 pounds of cotton seeds are recovered and utilized. The seeds yield 888 pounds of hulls, 23 pounds of linters, and 1,090 pounds of meats. The hulls yield bran which goes into cattle feed, and fiber which goes into the making of paper. Parts of the hull, unsatisfactory for either of these, are used as fertilizer material.

Cotton linters, or the fibers which cling to the seed after ginning, serve as the raw material for numberless synthetic cellulose products—rayon, lacquers, films, and all the rest of this family of products.

The 1,090 pounds of cottonseed meats yield 800 pounds of cattle feed and 290 pounds of cottonseed oil. The cottonseed oil finds its way into salad dressings, liquid cooking oils, cooking oils solidified by hydrogenation, and soaps.

In the picture on page 484 we see an American girl dressed in her wedding costume; she is clad from head to toe (except her shoe soles) in synthetic materials. Her dress is of cellulose acetate fiber (celanese) and viscose rayon combined; her stockings are of Bemberg rayon; her underwear is made of fibers produced by the nitrocellulose process (tubize); and her veil is of tulle—also a nitrocellulose product. Besides the textile fabrics used in the bride's costume, other synthetic materials are in evidence. The beads are of collodion with fish scale essence as the iridescent material placed in thin-walled glass spheres. The orange blossoms are precipitated calcium carbon-

ate coated with paraffin. Her slippers are of rayon and metal threads, the metal a tin-copper alloy. Even the traditional garter, embodying something old, something borrowed, and something blue, is made of rubber rendered adaptable by chemical treatment, and is covered with rayon and ornamented

A SYNTHETIC WEDDING COSTUME

Everything this young lady has on—veil, orange blossoms, beads, dress, stockings, shoes, jewelry—is made from products which once were discarded as waste material.

with rayon roses. The entire bridal costume was produced at a cost of less than $25.

And as for the remainder of the bride's trousseau, she now has an unlimited number of synthetic textile fabrics to choose from—brocaded rayon velvets; rayon fabrics for sport wear;

charming color effects made by combining two kinds of rayon with different dyeing properties; and dresses and shawls embroidered with lustrous rayon threads; hats of rayon, of rayon plush, or of Cellophane; beads of collodion, of glass, of casein, or of bakelite.

THE POSSIBILITIES IN FARM WASTES

Dr. Charles M. A. Stine, chemical director of E. I. du Pont de Nemours Company, in a recently published article on "The Chemist's Aid to Agriculture," shows the remarkable potentialities in farm products now wasted:

It has been estimated that there is an annual supply of by-products produced by agriculture in this country, somewhere in the neighborhood of 750,000 tons. These by-products or wastes consist of cereal, flax and rice straws, sugar cane bagasse, corn stalks and cobs, oat hulls, peanut hulls, cull potatoes and lemons, unmarketable dried fruits, the residue from beet sugar manufacture, and the skins and pits of all kinds of fruits. The development of various types of building material such as wall-board from agricultural wastes like bagasse from sugar cane, the manufacture of solvents and of starch from materials of agricultural origin, the manufacture of paper, of lacquers, and of rayon, all depend upon materials of organic origin.

A comparatively recent development in the utilization of agricultural waste materials is the manufacture of furfural from oat hulls. This material has become a large-scale industrial product, being sold in tank car lots, and is utilized in a variety of products.

The opinions of those who have thought and written about this question of the development of factory outlets for farm products ranges all the way from those who predict a time when the factory will use more of the farm products than will be consumed for food, to the opinion of those who look on the economic utilization of such agricultural wastes as a very limited possibility.

At present it should be said that while there are definite commercial factory outlets for some of these waste products, not much more than a beginning has been made along these lines. Wheat straw is used in quantities for the production of corrugated board for

shipping containers. Recently, the preparation of cellulose from cornstalks on a factory scale has been commenced. The manufacture of a building board from sugar-cane bagasse has attained considerable proportions, with the result that some additional sugar cane areas are being planted in the South because of the favorable effect upon this industry brought about by the price received for bagasse.

A very good insulating material for the modern home is made from straw of seed flax, and ground peanut hulls have been used to a limited extent in building construction.

I do not know where the greatest demand for the utilization of farm products may be, but certainly the demand for waste utilization in the corn and wheat belts of our central states is a very important one because of the considerable quantities of these materials which are available without paying high freight charges for their assemblage at some central consuming point. These waste materials contain cellulose and products closely related to it, and there is still a great deal of chemical work to be done to find out how to utilize to the best advantage products of this nature.

The rising cost of wood has served to emphasize the importance of this type of chemical research because economic conditions are likely to demand the substitution of cellulose from wood by other cellulose from cheaper sources.

I am informed that there is a foreign process which produces a binder for coal briquettes from the products of decayed vegetable fibers and that biochemical processes for employing molds and bacteria under carefully controlled conditions to break up the elementary raw materials and by-products into useful products for industry are becoming of increasing importance.

The chemistry of the utilization of agricultural products and by-products or wastes is still in its infancy.

A GOVERNMENT APPROPRIATION FOR FARM WASTES

Not very long ago, the United States Congress voted an appropriation of $50,000 to be devoted to research on the utilization of farm waste products. The Bureau of Standards was designated as the agency to supervise the work. Dr. Warren E. Emley, chief of the organic and fibrous materials division of the Bureau of Standards, entered into a coöperative

agreement with Professor O. R. Sweeney, of the Chemical Engineering Laboratory of Iowa State College at Ames, Iowa, whereby that college should undertake studies on the utilization of cornstalks as a part of the program. The State of Iowa made supplementary appropriations to assist in this work.

As a result, an experimental mill was built at Ames, and some remarkable results have been obtained. The first cornstalk product obtained was a wallboard and insulating board of excellent quality. More refined articles then followed in due course. At Danville, Illinois, the first plant was built for converting cornstalks into pulp, out of which paper, rayon, and other cellulose products could be made.

RESCUING STUFF FROM THE SCRAP HEAP

Whereas coal tar and cellulose by-products are among the most fascinating of the synthetic substances made by the creative chemist, many other important types of materials have been rescued from the scrap heap in man's struggle for stuff.

Wool recovered from fabrics that have already seen service, and derisively called "shoddy," keeps no inconsiderable portion of the human race warm. Whereas reworked wool can in no way be as good as the better grades of new wool, it is better than some of the poorer grades; and it serves its purpose by piecing out the virgin-wool supply.

Cork waste is used for many purposes—mattresses for gymnasiums, fillers for linoleums, insulation for refrigerators, coatings for heating pipes, and an ingredient of insulation boards.

Skim milk was formerly thrown away by many buttermakers. But this is the part of milk from which cheese is derived. Cheese-makers, in turn, formerly disposed of the remaining whey as best they could, but whey contains a milk sugar called lactose which is used to modify cow's milk and convert it into a food suitable for human babies.

Early silver miners threw away a product which we now know to be the mineral cerusite, or lead carbonate. We now recover this and sell it for something over one thousand dollars a ton.

The early Colorado miners execrated tungsten minerals whenever they found them, because they interfered with the process of recovering silver and other metals that they were interested in. Platinum was thrown away in South America in early mining practice, and radium was discarded in the waste ores from the Bohemian pitchblende mines, until the latter part of the last century.

By-product metals are now not only saved during mining and smelting, but small quantities of metals are recovered from every conceivable type of waste product.

A good bronze paint pigment is made from alloy waste.

Nickel is recovered from rolled or cast anodes and from the residue collecting in the bottom of an electric cell in which this metal is used. Waste gold is extracted from electro-gilding baths, from old photographic toning baths, from tailings, and from pieces of broken glass and pottery that have been gilded with gold-containing paints. Thousands of dollars' worth of silver is recovered each year from discarded movie films. The tin compound used to weight silk fabrics comes, to quite an extent, from old tin cans.

Many old rubbish heaps, the accumulations of years, have been exploited in recent times to good advantage. One such heap piled outside a certain factory covered 450 acres of land in 1888, and was receiving an addition of 1,000 tons of material a day. This has now all been converted into such valuable products as sodium carbonate and calcium sulphide, worth thousands of dollars.

A FISH STORY

The fish market is a place associated in rhyme and fiction with a medley of bad smells. But many things besides fish

and disagreeable odors are now obtained from this source. Bits of scrap are saved and extracted for their oil content. This oil may be hydrogenated to a solid fat, although the chemist still has to find some means of removing its odor completely. The scrap formed after the oil is removed serves as an excellent fertilizer.

Even fish scales have come to serve the human race. If scales are treated chemically with ammonia, the iridescent material may be separated. And if this material is mixed with a cellulose solution and placed in a thin-walled glass bead, it yields a pearl which rivals Cleopatra's famous gem in beauty, and which could never come to such a sorry end because it is insoluble in acids.

AN INGENIOUS POWER PLANT OF THE MIDDLE AGES

Our present-day efforts at generating power may seem as humorous as those above a few centuries hence. (Woodcut from Agricola, *De Re Metallica.*)

CHAPTER XXVII

STUFF OF THE FUTURE

Stuff of the moon
Runs on the lapping sand
Out to the longest shadows.
—Carl Sandburg

WHAT of the stuff of the future?

Pessimists say that we are fast using up our natural resources, and that future generations will lack some of the important materials which we now consider common. Optimists, on the other hand, point to the achievements of science and believe that, no matter what happens, the chemist can conjure new types of stuff from the air, or the ocean, or the moon, like a magician taking rabbits out of a borrowed hat.

There is no doubt that some of our natural resources are being used up rapidly—too rapidly in many cases. The pessimist does not need to look upon the situation as hopeless, however. Nor can the optimist afford to sit supinely back, thinking that man's supply of stuff will be taken care of in some mysterious fashion without conscious effort on the part of any one. If one type of material runs low, other types will undoubtedly be found to take its place. This will come about, however, only as the result of untiring research on the part of the scientist and of unceasing interest and sympathy on the part of the nonscientist. Raw materials, now sometimes used quite recklessly, must also be conserved in order to give the scientist something with which to work.

The story of the incinerator is interesting in this connection. A certain factory in our country produces wood dust as a waste material. For years this was burned in the incinerator in order

to get rid of it. By and by, a piece of chemical research disclosed the fact that wood waste could be used as the raw material for making products considerably more valuable than the main product to which the company had previously devoted its exclusive attention. Before this fact became known, it is estimated that millions of dollars' worth of stuff had been

WHAT LIES IN THE OCEAN?

burned up. When the incinerator passed out of use, the company placed an inscription on it which should serve as a lesson to other industries that are literally or figuratively maintaining incinerators.

No single article better exemplifies the twofold lesson of the possibilities of scientific research and the need for conserving the lowliest of raw materials than the peanut hull. This waste material, long the bane of the small town motion picture theater janitor, has recently been shown by the chemist to be a veritable

Pandora's box of useful and beautiful materials. These range all the way from an artificial marble, used by the building trades, to a rayon, the chemist's charming textile creation. By demonstrating the fact that the peanut hull has possibilities previously unimagined, the scientist has not only acquired an important raw material, but he has revolutionized the agricultural habits of some of our Southern States. The culture of peanuts began to grow by leaps and bounds when it was found that the hull was more important than the nut.

WHAT LIES UNDER PEACEFUL MT. NITTANY?

History has failed to record whether or not the Egyptians of the time of Rahotep and Nefert, the prince and princess who lived about half a hundred centuries ago at the dawn of what we choose to call civilization, knew the peanut or not. If they did, they were certainly not aware of the secrets which lay hidden in its outer protective covering. Had Prince Rahotep

and Princess Nefert lived in a time when man had produced aluminum for use in airplanes, bakelite for panels in radio sets, alloy steels strong enough for armor plate, human food from the cotton seed, stainless steel for table knives, metallic sodium for television tubes, rainbow colors from coal, tungsten for electric light filaments, and rayon for court costumes, they would undoubtedly have been even more smug than their statues show them to have been.

STUFF EVERYWHERE

What stuff of the earth, or the sky, or the sun, or the moon will future generations use to make their lives happier and more comfortable?

Perhaps, thousands of years from now, the generations which will inhabit the globe will look back at us and wonder that we could have been so contented when we had so little!

What of the energy of the future?

In former times we were accustomed to draw a fairly well defined division line between chemistry, or the science of mate-

rials, and physics, or the science of energy. As man learns more about the structure of stuff and the nature of energy, these artificial distinctions are fading away. Modern experimental and mathematical science shows that matter and energy are probably but different manifestations of the same thing. Science has penetrated into the secrets of the structure of matter, first as far as the molecule, then as far as the atom, and finally it has established beyond a question the existence of the electron. Now it would seem that the electron is but one manifestation of wave motion. If this is true, our hunt for materials is more thoroughly bound up with our quest for energy than we had previously thought.

Be this as it may, man will continue to measure his progress by the stuff which he learns to make and use, and the energy which he learns to harness.

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